Journal of Dry Zone Agriculture

Volume 4, Number 2
November 2018

FACULTY OF AGRICULTURE, UNIVERSITY OF JAFFNA, SRI LANKA
ISSN 2012-8673

Journal of Dry Zone Agriculture, Vol. 4, No. 2, November 2018

ISSN 2012-8673

Editorial Policies

The Journal of Dry Zone Agriculture (JDZA) publishes original research articles covering all aspects of dry zone agriculture. Authors preparing manuscripts should follow the instructions appearing at the end of this volume. All opinions reflect the views of the authors and are not necessarily the views of Faculty of Agriculture, University of Jaffna. Final decision of the acceptance or rejection of the papers is made by the editors.

The JDZA is devoted to sustain the standard through a rigorous blind review along with strict ethical policies. The JDZA publishes original research works that have not been published in any form except abstract or not currently under consideration for publication elsewhere. Any violations of professional ethical codes such as plagiarism, fraudulent use of data and bogus claims of authorship are taken seriously by the editors. Authors are expected to acknowledge the funding sources. Copyright materials must be reproduced only with the permission and acknowledgement. Authors should ensure that text, equations or figures from published sources have been cited.

Published in November 2018 by the Faculty of Agriculture, University of Jaffna, Ariviyal Nagar, Kilinochchi, Sri Lanka.
URL: www.jdza.jfn.ac.lk
Printed by: Harikanan (Pvt) Ltd., No. 681, K.K.S. Road, Jaffna, Sri Lanka

Editor's Note

As the chief editor, it is a great pleasure and privilege to publish the Journal of Dry Zone Agriculture (JDZA), volume 4 of the Faculty of Agriculture, University of Jaffna, Sri Lanka. For the first time in history, the JDZA is published in two issues, however, due to unavoidable circumstances, we were unable to publish these issues according to schedule. I am sure that, issue 1 and issue 2 of the future volumes will be published in May and November, respectively.

The objective of the JDZA is to publish up-to-date and high-quality research findings, focusing on all facets of the dry zone agriculture. This volume consists of twelve full length research articles of selected abstracts presented at the 3rd International Conference on Dry Zone Agriculture (ICDA) hosted in 2017, with post-peer review process.

Agriculture is the mainstay of the Sri Lankan economy. The recent unpredictable climate changes and extreme weather conditions have been threatening the food production systems in the dry zone of Sri Lanka. Thus, innovations in dry zone agriculture become inevitable to address the issues related to climate change and dissemination of these findings is crucial to apply them practically in the field. Thus, I have no doubt that JDZA will definitely contribute to the development of dry zone agriculture in Sri Lanka.

I wish to extend my sincere gratitude to the authors, reviewers, editors, editorial assistant and everyone who contributed immensely towards the successful publication of this volume of the JDZA. I would also like to acknowledge the financial support provided by the University of Jaffna to publish the journal. Finally, I am confident that, the future volumes of this journal will carry more number of research findings with realistic solutions to the dry zone agriculture.

Subajiny Sivakanthan
Editor-in-Chief

List of Contents

Journal of Dry Zone Agriculture, 2018, 4(2): 49- 56

ISSN 2012-8673

Yield and Nutritive Value of Palmyrah *(Borassus flabellifer)* Leaves at Different Stages of Maturity

Sarmini, M.[1] and Premaratne, S.[2]

[1]*Department of Animal Science, Faculty of Agriculture, University of Jaffna, Sri Lanka*
[2]*Department of Animal Science, Faculty of Agriculture, University of Peradeniya, Sri Lanka*

Abstract: Present study was conducted to evaluate the yield and nutritive value of palmyrah (*Borassus flabellifer*) leaves at different growth stages to find out its forage nutritive value. Palmyrah leaf samples were collected from three male and female palms at seven growth stages (5, 10, 15, 20, 25, 30 and 35 months). Fresh and dry matter weights of the leaves were measured. Dried leaves were ground into 1 mm particles and analyzed for their nutrient composition using standard procedures. There was no significant difference (p>0.05) between male and female palms for most of the parameters studied (dry matter (DM), crude protein (CP), crude fiber (CF), ash and gross energy (GE). Leaf weight varied from 0.91 to 1.22 kg/leaf and 0.91 to 1.30 kg/leaf (DM basis) in male and female palms, respectively. The range of values of nutrient composition of leaves from male and female palms were: CP 10.1-14.4% and 10.1-14.4%; CF 35.5 - 48.1% and 35.7 - 49.3%; calcium (Ca) 1.34 - 4.30% and 1.52 - 4.53% and phosphorous (P) 0.24 - 0.44% and 0.20 - 0.4 0%, respectively. *In vitro* dry matter digestibility (IVDMD) and GE were ranged between 39.72 – 53.99% and 38.06 – 51.28% and 4.35 - 4.55 Mcal/kg and 4.37 - 4.61 Mcal/kg for leaves of male and female palms, respectively. The CP, IVDMD, GE and phosphorus contents were decreased with advancing maturity, whereas, CF and Ca were increased. Accordingly, leaves harvested from both male and female palms at 10 to 30 months of age have a good forage value in terms of CP, IVDMD and fodder yield to be used as ruminant feed.

Keywords: forage-value, growth-stages, leaf weight, nutrient composition

Introduction

The agro-climatic condition of the Northern region is suitable for growing good quality tropical forages (Houwers *et al*., 2015). Palmyrah (*Borassus flabellifer*) is growing naturally in forest, waste lands, plantations and home gardens of the Northern and Eastern Provinces of Sri Lanka (Theivendirarajah, 2008). Fodder production shows a seasonal pattern in Sri Lanka due to the non-uniform

Corresponding author: M. Sarmini, e-mail: *sarmini30@gmail.com*

rainfall pattern. By virtue of the extensive deep rooting system, palmyrah palms are able to withstand severe drought conditions and provide quality green fodder during dry periods in the Northern and Eastern parts of Sri Lanka. Palmyrah palms are dioecious and the leaves (lamina) of palmyrah are a good source of forage for ruminants (Theivendirarajah, 2008). According to Mohanajeyaluxmi (1986), the nutrient compositions of palmyrah leaf lamina after removing the petioles and midribs were superior in quality, especially in crude protein.

A palm starts to sprout a fully developed leaf at the age of two years and it continuously produces a new leaf every month, thereafter. Therefore, the terminal crown of mature palms at the age of 5 years and above have about 30 to 40 fan-shaped green leaves (Theivendirarajah, 2008). Since the number of leaves present in a mature palm varies with maturity, the yield and nutrient composition of leaves present in a palm varies. According to Oelberg (1956), the stage of growth seems to be the most important factor affecting the chemical composition and digestibility of range forage. Therefore, the study aimed to evaluate the yield and nutritive value of palmyrah leaves at different stages of maturity in order to find out the forage value.

Materials and Methods

Collection and preparation of samples

The leaves of three male and female palmyrah palms (10 to 15 years of age) of variety black skin fruit at different growth stages were collected from Kilinochchi district. Basic data regarding the height, girth and leaf number were measured. The leaves were manually harvested at seven stages of growth (5, 10, 15, 20, 25, 30 and 35 months of age) from male and female palms. Fully sprout top leave was considered as one month age and the age of the subsequent leaves was calculated from top to bottom. Fresh matter (FM) and dry matter (DM) yields of harvested leaves were measured. The leaves were cut from the petiole and all the midribs were removed, leaving the strips of the leaf blade and these were again split into smaller strips and dried in an oven at 60 °C until a constant weight is reached. All the samples were ground to 1 mm particles using a laboratory grinder and stored at room temperature for the chemical analysis.

Chemical analysis

Dry matter (DM), ash, crude protein (CP), crude fiber (CF) and ether extract (EE) of the samples were determined according to the AOAC (2005) procedure. *In vitro* dry matter digestibility (IVDMD) was determined according to Tilley and Terry method (1963) as modified by Van Soest and Robertson (1985). Gross Energy (GE) content was measured using a Bomb calorimeter (AOAC, 2005). Calcium content was measured using atomic absorption spectrophotometer and phosphorus content was measured using spectrophotometer (AOAC, 2005).

Data analysis

Data were subjected to Analysis of Variance Procedures (ANOVA) using Statistical Analysis Software version 9.1.3 (SAS, 2009) to determine the statistical significance between the palmyrah leaves at various growth stages. Mean comparisons were done using Duncan's multiple range test (DMRT).

Results and Discussion

Growth parameters of male and female palms at the time of harvesting

The data regarding the height, girth and leaf number of male and female palmyrah palms at the time of sample collection are given in Table 1. Even though the values were not significantly differed ($p>0.05$), male palms had more number of leaves than the female palms.

Fresh and dry weight of palmyrah leaves

Fresh and dry weight of palmyrah leaves at different growth stages are presented in Table 2. There was no significant difference ($p>0.05$) between male and female palms for dry weight in all stages of growth except for 35 months of age (L 35). However, dry weight observed after 10 months of maturity was significantly higher ($p<0.05$) than the weight observed before 10 months of maturity. The average fresh weight of lamina of a single leaf was 2 kg, whereas a palm had an average of 36 to 38 leaves. Therefore, about 20 leaves can be harvested from a mature palm and the total weight of green matter available from a palm is around 40 kg. Palms (n=1110) can be grown in one hectare of land (3m×3m) (E-agriculture, 2015). Therefore, an average of 44,400 kg of fresh matter/ha can be harvested from a mature palm at a growth of 5 years. Subsequently, an average of 12 leaves can be harvested every year with a fresh weight of 2 kg. Thus, an annual fresh yield of 26,640 kg/ha can be harvested for about 70 years. Accordingly, a palmyrah palm will provide 1680 kg of green forage on average for ruminant in its lifetime.

Nutrient content of palmyrah leaves

The nutrient content of male and female palmyrah leaves (DM basis) at different growth stages is presented in Table 3. The respective DM, CF and Ca contents of palmyrah leaves increased ($p<0.05$) with the advancement of leaf growth (Table 3). The DM content of 46% and ash content of 4.5% reported by Mohanajeyaluxmi (1986), and ash content of 6.8% reported by Perera (1992) for a mixture of leaves were within the range of current results. The greater value obtained for ash indicates that most leaves may be considered as a satisfactory source of minerals (Oelberg, 1956). The Ca content of leaves was observed to increase uniformly from early stage to maturity. This observation can be attributed to the increased amount of cellular material which is the principal element of Ca (Oelberg, 1956). Further, Cook and Harris (1950) stated that the Ca was found to increase with growth in all plants and plant parts. When a plant matures, it becomes more fibrous, which may be the cause of an increase in CF content. This finding was in agreement with the finding of Oelberg (1956), who stated that the trend in CF content in regard to stage of maturity is normally the reverse of protein.

Table 1: Height, girth and leaf number of male and female palms at the time of sampling†

Type	Height (m)	Girth (m)	Number of leaves
Male Palm	11.2±0.5	1.12±0.1	38.0±2.3
Female Palm	11.5±0.3	1.30±0.1	36.0±1.4

† Means ± Standard error

Table 2: Fresh and dry weight of palmyrah leaves at different growth stages†

Leaf number (Maturity)	Type	Fresh weight, kg	Dry weight, kg
L5	M	2.01^{bc}±0.01	0.91^{d}±0.01
	FM	1.92^{c}±0.02	0.91^{d}±0.02
L10	M	2.03^{bc}±0.03	1.10^{c} ±0.02
	FM	1.96^{c}±0.02	1.05^{c}±0.02
L15	M	2.06^{bc}±0.03	1.18^{b}±0.03
	FM	2.17^{a}±0.03	1.20^{b}±0.01
L20	M	2.09^{b}±0.03	1.22^{b}±0.01
	FM	2.19^{a}±0.01	1.26^{ab}±0.01
L25	M	2.05^{bc}±0.06	1.22^{b}±0.01
	FM	2.17^{a}±0.02	1.27^{ab}±0.01
L30	M	1.97^{c}±0.01	1.23^{b}±0.01
	FM	2.15^{ab}±0.02	1.27^{ab}±0.02
L35	M	1.91^{c}±0.01	1.23^{b}±0.01
	FM	2.15^{ab}±0.03	1.30^{a}±0.04

†Means ± Standard error

^{a,b,c} Means with different superscripts within a column are significantly different ($p<0.05$)

L 5- Leaves at five months age, L 10- Leaves at ten months age, L 15- Leaves at fifteen months age, L 20- Leaves at twenty months age, L 25- Leaves at twenty five months age, L 30- Leaves at thirty months age, L 35- Leaves at thirty five months age

Crude protein, EE, IVDMD and P contents of the leaves decreased ($p>0.05$) as the leaves advanced in growth (Table 3). The CP content of the leaves at all stages of maturity was above 10%. However, the CP content of the leaves after 25 months of age was lower ($p<0.05$) than the value obtained before 25 months of age. Crude protein levels below 8.0% on dry matter basis are considered insufficient to meet the maintenance requirements of ruminants (Ibrahim, 1988). Van Soest (1994) suggested that CP content of browse species should be higher than the minimum level of 7-8% of DM for optimum rumen function and feed intake in ruminant animals. The CP content of palmyrah leaves at all stages of harvest of the present results is sufficient to meet the minimum level of CP requirement. The CP content of 13-15% reported by Mohanajeyaluxmi (1986), and 12% reported by Perera (1992) for the mixture of leaves were within the range reported in the present study.

IVDMD of the harvested leaves at all stages of growth was below 55% (Table 3). Further, IVDMD values were (below 45%) lower ($p<0.05$) after 30 months of age compared to the leaves harvested before 30 months of age (Table 3). The lower IVDMD values were closely related to the higher lignin content (Ibrahim, 1988). According to Jayawardena and Perera (1991), the digestibility content below 45% of most fodders is considered a limiting factor for feeding livestock.

Table 3. Nutrient content of palmyrah leaves at different growth stages †

LN	Type	Chemical composition (g/100 g DM)							
		DM	CP	EE	CF	Ash	NFE	Ca	IVDMD
L5	M	0.3^{j}±0.13	14.4^{a}±0.05	4.58^{a}±0.06	35.5^{g}±0.15	4.5^{fg}±0.03	41.1^{a}±0.07	1.34^{j}±0.14	53.9^{a}±3.05
	FM	47.4^{i}±0.23	14.4^{a}±0.06	4.54^{a}±0.06	35.6^{g}±0.19	3.81^{g}±0.23	41.6^{a}±0.14	1.52^{i} ±0.31	51.3^{b}±1.57
L10	M	54.2^{g}±0.15	13.9^{ab}±0.09	4.51^{a}±0.05	38.1^{f}±0.21	4.84^{e}±0.31	38.7^{b}±0.17	2.99^{g}±0.12	51.7^{b}±1.64
	FM	53.4^{h}±0.26	13.9^{ab}±0.05	4.46^{a}±0.06	37.0^{f}±0.17	5.32^{cde}±0.04	39.3^{ab}±0.08	1.69^{h}±0.15	50.1^{bc}±2.15
L15	M	57.4^{f}±0.18	13.7^{ab}±0.15	4.39^{b}±0.09	39.1^{e}±0.34	5.27^{de}±0.09	37.5^{b}±0.17	3.66^{e}±0.14	49.1^{cd}±2.01
	FM	55.4^{g}±0.28	13.8^{ab}±0.09	4.38^{b}±0.04	40.8^{e}±0.38	6.39^{c}±0.12	34.6^{c}±0.16	2.94^{h}±0.31	49.1^{cd}±2.78
L20	M	58.3^{e}±0.15	13.4^{bc}±0.16	4.32^{b}±0.05	40.7^{d}±0.07	5.59^{cde}±0.24	36.0^{b}±0.13	3.81^{d}±0.14	47.5^{d}±3.10
	FM	57.5^{f}±0.13	13.7^{ab}±0.03	4.37^{b}±0.06	41.5^{d}±0.26	6.48^{c}±0.15	33.9^{c}±0.13	3.31^{f} ±0.12	45.4^{e}± 2.15
L25	M	59.6^{d}±0.13	12.9^{d}±0.12	4.32^{b}±0.06	41.4^{c}±0.18	6.24^{cd}±0.16	35.1^{b}±0.13	3.82^{c} ±0.14	45.4^{e}±1.92
	FM	58.4^{e}±0.16	12.4^{d}±0.09	4.34^{b}±0.04	43.3^{c}±0.46	7.90^{b}±0.13	32.1^{d}±0.18	3.82^{d} ±0.17	43.7^{e}±2.41
L30	M	62.4^{b}±0.29	11.1^{e}±0.06	4.26^{b}c±0.09	43.6^{b}±0.32	8.20^{b}±0.12	32.8^{d}±0.15	4.27^{b} ±0.29	40.0^{f}±1.85
	FM	59.1^{d}±0.09	11.3^{e}±0.17	4.29^{b}c±0.04	43.8^{b}±0.14	8.12^{b}±0.14	32.4^{d}±0.12	4.18^{c}±0.13	41.7^{f} ±1.92
L35	M	64.5^{a}±0.18	10.1^{f}±0.15	4.20^{c} ±0.06	48.1^{a}±0.51	9.22^{a}±0.23	28.5^{e}±0.06	4.30^{b} ±0.11	39.7^{g}±3.01
	FM	60.5^{c}±0.17	10.1^{f}±0.13	4.26^{b}c±0.06	49.3^{a}±0.38	8.69^{b}±0.09	27.7^{e}±0.17	4.53^{a} ±0.08	38.1^{g}±2.41

†Means ± Standard error

^{a,b,c,d,e,f,g,h,i,j}Means with different superscripts within a column are significantly different ($p<0.05$)

LN- Leaf Number, M – Leaves from male palms, FM – Leaves from female palms, DM- Dry matter, CP – Crude Protein, EE- Ether extract, CF – Crude fiber, NFE- Nitrogen Free Extract, IVDMD- *In vitro* dry matter digestibility

L 5- Leaves at five months age - L 10- Leaves at ten months age, L 15- Leaves at fifteen month age, L 20- Leaves at twenty months age, L 25- Leaves at twenty five months age, L 30- Leaves at thirty months age, L 35- Leaves at thirty five months age

Table 4: Gross energy contents of male and female palmyrah leaves (DM basis) at various growth stages†

Item	Type	L 5	L 10	L 15	L 20	L 25	L 30	L 35
GE (Mcal/ kg)	M	$4.55^{a}\pm0.06$	$4.48^{ab}\pm0.08$	$4.45^{ab}\pm0.20$	$4.40^{b}\pm0.25$	$4.39^{b}\pm0.03$	$4.36^{bc}\pm0.99$	$4.35^{bc}\pm0.03$
	FM	$4.61^{a}\pm0.02$	$4.52^{ab}\pm0.01$	$4.45^{ab}\pm0.23$	$4.42^{ab}\pm0.01$	$4.39^{b}\pm0.01$	$4.38^{b}\pm0.01$	$4.37^{bc}\pm0.01$

†Means ± Standard error

^{a,b,c}Means with different superscripts within a raw are significantly different ($p<0.05$)

M – Leaves from male palms, FM – Leaves from female palms, GE- Gross energy content

L 5- Leaves at five months age - L 10- Leaves at ten months age, L 15- Leaves at fifteen months age, L 20- Leaves at twenty months age, L 25- Leaves at twenty five months age, L 30- Leaves at thirty months age, L 35- Leaves at thirty five months age

GE contents were reduced from 4.55 to 4.35 Mcal/kg in leaves of male palms and 4.61 to 4.37 Mcal/kg in leaves of female palms with the advancement of growth (Table 4). The ME content was calculated and it reduced from 1.45 to 0.73 Mcal/kg and 1.37 to 0.79 Mcal/kg in leaves of male and female palms, respectively with growth. Maturity had no significant effect (p<0.05) on the GE and ME content of palmyrah leaves.

Study of Oelberg (1956) explained that the ME of leaves decreased with advancement of growth due to increase in cell wall contents. A study of Khanum *et al*. (2007) stated that the ME values were very low in feedstuffs (included various grasses, crop residues and some tree leaves) having high fiber and low protein contents. This may be the reason for the low ME values observed in leaves harvested after 30 months of growth.

Leaves harvested before 10 months of age had lower weight in comparison to after 10 months of age due to leaf immaturity, whereas leaves harvested after 30 months of age had lower IVDMD due to higher indigestible materials.

Conclusion

Harvesting of leaves at an early stage will affect the growth of the palms. Crude protein, CF, IVDMD and ME content of the leaves harvested between 10 and 30 months of the mature stage showed acceptable values for feeding ruminants. Therefore, it could be concluded that, leaves harvested between 10 and 30 months of growth stages could have a forage value.

Acknowledgements

The authors acknowledge the University Grants Commission (UGC) for the financial assistance (Grant Number: UGC/VC/DRIC/ PG2016(I) /UJA/01).

References

AOAC. 2005. Official Methods of Analysis of AOAC International, 18th Ed: Association of Official Analytical Chemists, Maryland, USA.

Cook, C. W. and Harris, L. E. 1950. The nutritive value of range forage as affected by vegetation type, site and stage of maturity. Technical Bulletin: UTAH Agricultural Experiment Station, 344:45.

E-agriculture. 2015. Complete information about palmyrah. [Accessed on 03.10.2016]. Available at (http://www. eagriculture. in/package-of-practices-of-palmyra).

Houwers, W., Wouters, B. and Vernooij, A. 2015. Sri Lanka fodder study; An overview of potential, bottlenecks and improvements to meet the rising demand for quality fodder in Sri Lanka. Lelystad, Wageningen UR (University & Research center) Livestock Research, Livestock Research Report, 924.

Ibrahim, M.N.M. 1988. Feeding tables for ruminants in Sri Lanka. Kandy Offset Printers Ltd., Kandy, Sri Lanka.

Jayawardena, V.P. and Perera, A.N.F. 1991. Evaluation of Under-utilized Fodder Species for Feeding Small Ruminants in Sri Lanka. Tropical Agricuitural Research. 3:339-347.

Khanum, S.A., Yaqoob, T., Sadaf, S., Hussain, M., Jabbar, M.A., Hussain, H.N., Kausar, R. and Rehman, S. 2007. Nutritional evaluation of various feedstuffs for livestock production using in vitro gas method. Pakistan Veterinary Journal, 27:129–133.

Mohanajeyaluxmi, J. 1986. The chemistry and biochemistry of palmyrah products. M.Phil thesis, University of Jaffna, Sri Lanka.

Oelberg, K. 1956. Factors affecting the nutritive value of range forage. Journal of Range Management, 9:220–225.

Perera, A. N. F. 1992. Availability of tree and shrub fodder resources for ruminant livestock feeding in Sri Lanka. In: Yammasubhro, G., T. and Ivore, C. (Eds.) Proceedings of the 7th International Conference of Institutions of Tropical Veterinary Medicine, 1:233-238.

SAS. 2009. SAS/STAT User's Guide. Version 6.12, SAS Institute Inc., Cary, North Carolina, USA.

Theivendirarajah, K. 2008. Palmrah palm (*Borassus flabellifer* L). Grapharts print, Ontario, Canada. pp 67-69.

Tilley, J. M. A. and Terry, R. A. 1963. A two stage technique for In Vitro digestion of forage crops. Journal of British Grassland Society, 18:104-111.

Van Soest, P.J. 1994. Nutritional ecology of ruminants. 2nd ed. Cornell University Press Ithaca, New York, USA.

Van Soest, P. J. and Robertson, J. B. 1985. Analysis of forages and fibrous feeds. In: Laboratory Manual for Animal Science 613. Cornell University, Ithaca, New York.

Journal of Dry Zone Agriculture, 2018, 4(2): 57 - 64
©Faculty of Agriculture, University of Jaffna, Sri Lanka
ISSN 2012-8673

Distribution, Infestation and Occurrence of *Noorda blitealis* Wlk. and *Gitona distigma* (Meigen) in *Moringa oleifera* Lam. in the Home Gardens of Jaffna District, Sri Lanka

Sharjana, K. and Mikunthan, G.

Department of Agricultural Biology, Faculty of Agriculture, University of Jaffna, Sri Lanka

Abstract: *Moringa oleifera* Lam. is grown in Jaffna home gardens for pods and leaves. After the introduction of PKM 1 *Moringa* variety, the populations of leaf eating caterpillar (*Noorda blitealis* Wlk.) and pod fly [*Gitona distigma* (Meigen)] were suddenly increased causing severe damage in leaves and pods, respectively. Hence, this study was carried out to map the distribution of the insects and their occurrence in Jaffna District. The infestation of *N. blitealis* was reported in Maruthankerny, Velanai, Karaveddy, Chavakachcheri, Pointpedro, Kaytes, Nallur, Kopay, Kaithady, Jaffna, Uduvil, Thellipalai, Sandilipay and Chankanai Divisional Secretariat (DS) divisions. High infestation score of 4 (defoliation 76% -100%) was recorded in Maruthankerny, Velanai, Karaveddy, Chavakachcheri and Point Pedro DS divisions. *G. distigma* infestation was observed in Maruthankerny, Velanai, Chavakachcheri and Karaveddy DS divisions. The highest score of 4 (pod damage 76 -100%) was reported in Maruthankerny, Karaveddy and Velanai DS divisions. The caterpillar, *N. blitealis* larvae fed on the leaves and barks. It webbed, skeletonised and defoliated the tree completely. The pod fly, *G. distigma* maggots were found feeding in tender pods. The affected pods dried and split from the tips. Gummy exudates were found oozing out from the pods. A questionnaire survey carried out among *Moringa* growers in this district revealed that *N. blitealis* infestation increases in the rainy season during the months of October, November, December, January and February. Families used sanitary measures (92%), pruning (92%), hand picking (84%) and application of ash (33%), leaf extracts (25%), cow urine (16%) and insecticides (32%) to manage *N. blitealis* in their home gardens. Spacing of the plants showed a negative correlation and fertilizer application had a positive correlation with the severity of *N. blitealis*. Spiders, *Chrysoperla carnea*, *Cydonia vicina*, mantis and *Centropus sinensis* were recorded as predators on *N. blitealis*. Creating awareness among the public on these pests and their damage will help identify the pests easily and will also help to manage the problem using non-chemical means.

Keywords: forage-value, growth-stages, leaf weight, nutrient composition

Corresponding author: K. Sharjana, e-mail: *k.sharju@yahoo.com*

Introduction

Moringa oleifera Lam. (Family: Moringaceae) is one of the commonly grown multipurpose tree in Jaffna home gardens. It can survive in very harsh climate conditions especially the drought (Morton, 1991). All parts of *Moringa* have economic value in nutritional, medicinal and industrial perspective. Fahey (2005) pointed out that *Moringa* is the "natural nutrition for the tropics" as it is frequently used to fight malnutrition among infants and nursing mothers. Annual *Moringa*, Periyakulam 1 (PKM 1) variety, which was introduced from India for leaves and fleshy fruit, grows well in resettled home gardens of Jaffna district and bears continuously especially to fulfill the daily nutrition requirements of the families. The pods and leaves, which are rich of nutrients especially iron, are used for consumption. Seasonal pests have been a major limitation in *Moringa* grown in Jaffna district. After the introduction of PKM 1 variety, *Moringa* trees were severely attacked by a leaf eating caterpillar *Noorda blitealis* Wlk (Family: Pyralidae) and the pods were damaged by a *Moringa* fruit fly *Gitona distigma* (Meigen). The caterpillar feeds on the Moringa leaves and completely defoliates the tree during severe conditions (Satti *et al.*, 2013). Anjaneyamurthy and Regupathy (1992) reported that the Moringa fruit fly *G. distigma* (Meigen) attacks the pods and cause gummy exudates from the fruits. Since these pests are emerging as new pests in *Moringa*, information on these pests are lacking under Sri Lankan conditions. The *Moringa* growers in Jaffna are unaware of the pest damage and yield reduction. Considering the plight of the resettled families and others growing *Moringa* in home gardens in Jaffna district, this study was carried out as an initial work to determine the distribution, infestation and occurrence of *N. blitealis* and *G. distigma* in *Moringa* grown in the Jaffna District.

Materials and Methods

Recording the distribution and infestation

Field visits were conducted throughout the Jaffna District to observe and record the distribution and severity of infestation of *Moringa* using the severity score parameter. The infested fields were located and recorded with the help of Geographical Positioning

Table 1: Details of infestation severity score

Score	Infestation level by *N. blitealis*	Pod damage level by *G. distigma*
0	No leaf damage	No pod damage
1	1-25% defoliation	1-25% pod damage
2	26-50% defoliation	26-50% pod damage
3	51-75% defoliation	51-75% pod damage
4	76-100% defoliation	76-100% pod damage

(Source: Bedane *et al.*, 2013)

Table 2: Percentage of samples used for questionnaire survey form different DS divisions

DS division	Percentage of samples collected
Nallur	9
Point Pedro	5
Kopay	16
Jaffna	4
Velanai	6
Karaveddy	10
Maruthankerny	14
Uduvil	5
Chankanai	3
Sandilipay	4
Kaithady	2
Kayts	2
Thellipalai	7
Chavakachcheri	13
Total	100

(Source: Survey data, 2014, 2015)

System (GPS) device, the severity scores were given for the infested trees as shown in Table 1. Pointing out the distribution of *N. blitealis* was done using ARCVIEW GIS 3.29 version software. Damage and symptoms of *N. blitealis* and *G. distingma* were carefully observed and recorded.

Questionnaire survey on N. blitealis incidence in Jaffna District

A questionnaire based survey was conducted during the period of November 2014 to May 2015 in Jaffna District. The details of *Moringa* cultivators in Jaffna District were taken from Department of Agriculture (Extension). The survey was conducted with hundred randomly selected *Moringa* cultivators in home gardens to obtain data regarding the infestation level of *N.blitealis*, *Moringa* varieties cultivated, natural enemies association, cultivation practices and management methods. Interviews typically lasted for 20 minutes per *Moringa* grower. Table 2 shows the percentage of samples collected from 100 *Moringa* growers in Jaffna District.

Statistical analysis

The data obtained from questionnaire survey were statistically analyzed using SPSS (SPSS Inc. Released 2007. SPSS for Windows, Version 16.0. Chicago, SPSS Inc.)

Results and Discussion

The infestation of *N. blitealis* was found in Maruthankerny, Velanai, Karaveddy, Chavakachcheri, Pointpedro, Kayts, Nallur, Kopay, Kaithady, Jaffna, Uduvil, Thellipalai, Sandilipay and Chankanai DS divisions. High number of plants received the infestation score of 4 (76% -100% defoliation) in Maruthankerny, Velanai, Karaveddy, Chavakachcheri and Point Pedro DS divisions. Uduvil, Thellipalai, Sandilipay and Chankanai DS divisions received the lowest infestation score of 1 (1% - 25%. defoliation) (Figure 1).

G. distingma infestation was observed in Maruthankerny, Velanai and Karaveddy DS divisions. Infestation severity was high in Maruthankerny, Velanai, Chavakachcheri and Karaveddy DS divisions with the infestation score of 4 (76% -100% pod damage) (Figure 2).

The larvae of *N. blitealis* were found feeding on the ventral surface of the shoots and leaves. During the hot sunny days, the larvae enrolled the leaf blade using the silky thread and were found inside the rolled leaves. The larvae were found hanging with a silken thread which facilitated it to move from the upper branches to the lower branches in order to feed on the new leaves. The webbed leaf blades were translucent. The leaves were skeletonised, dried up and turned into brown in colour.

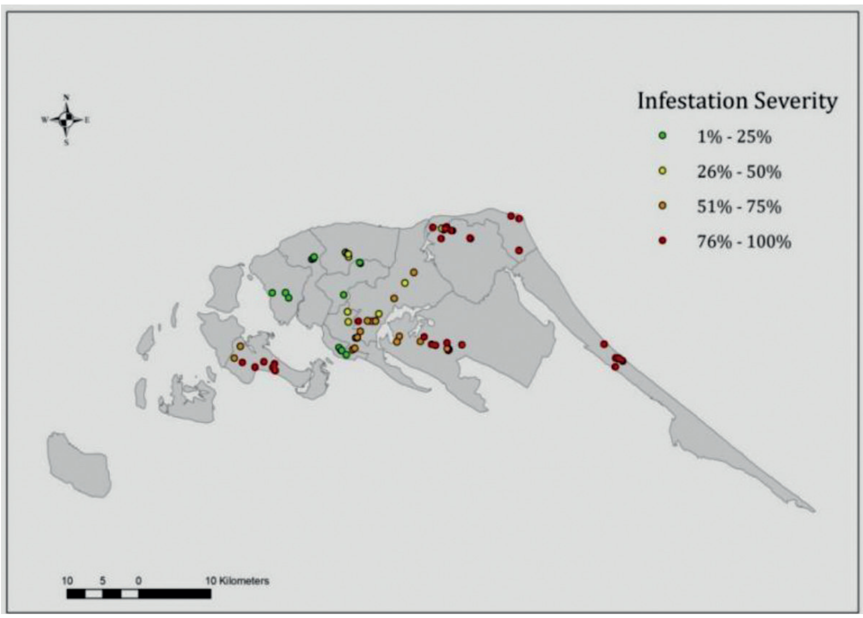

Figure 1: Distribution of *N. blitealis* Wlk. in Jaffna District

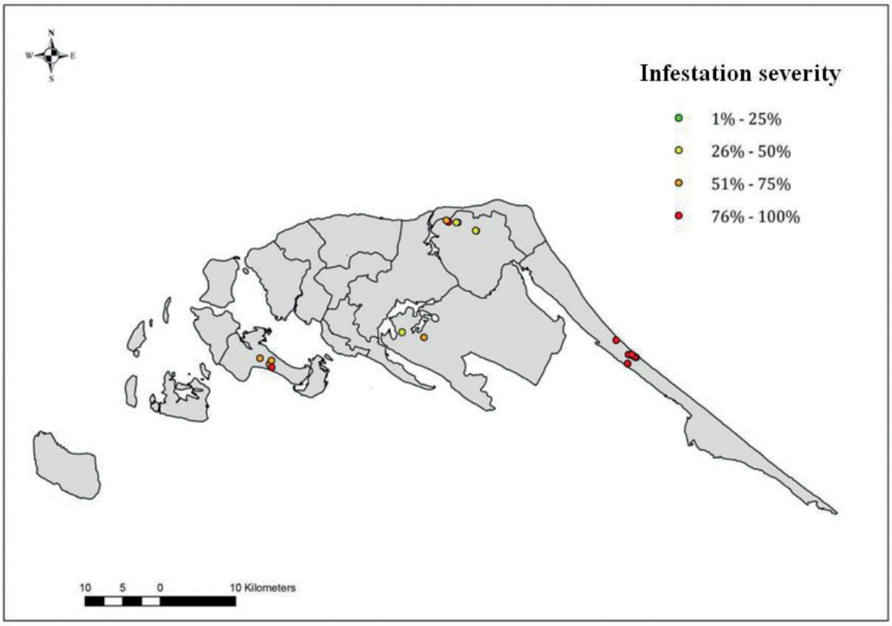

Figure 2: Distribution of *G. distigma* (Meigen) in Jaffna District

In severe infestation, complete defoliation was observed. Black faecal materials were found on the leaflets and were stuck with the silken threads on the tree. In pruned *Moringa* trees the larvae were found feeding on the stem (Figure 3).

The maggots of *G. distigma* were found in the *Moringa* pods. The maggot entered the pods through bored hole at the terminal end of the fruit. The pods turned to brown in colour and dried up. The pods split from the tip and the flesh of the fruit was exposed. Oozing of brown gummy exudates was observed. The flesh of the pod was found rotten due to the damage of the maggot and microbial infection. *Moringa* leaves and drumsticks were used for edible purposes. Both PKM 1 and traditional varieties were cultivated in the home gardens and commercial levels. Seedlings and stem cuttings were used as planting materials. Out of 100 *Moringa* cultivators, 86% used seedlings and 14% used cuttings as planting material. Among the 100 home gardens, 18% and 14% of planting materials were distributed by Grama Niladhari (GN) divisions and Non-Government Organization (NGO).

According to the Figure 5, the *N. blitealis* infestation started to increase in October and reached the peak in December, then gradually reduced up to March. It is obvious that infestation started with the onset of rainy season. Similar results were also reported by Bedane *et al*. (2013).

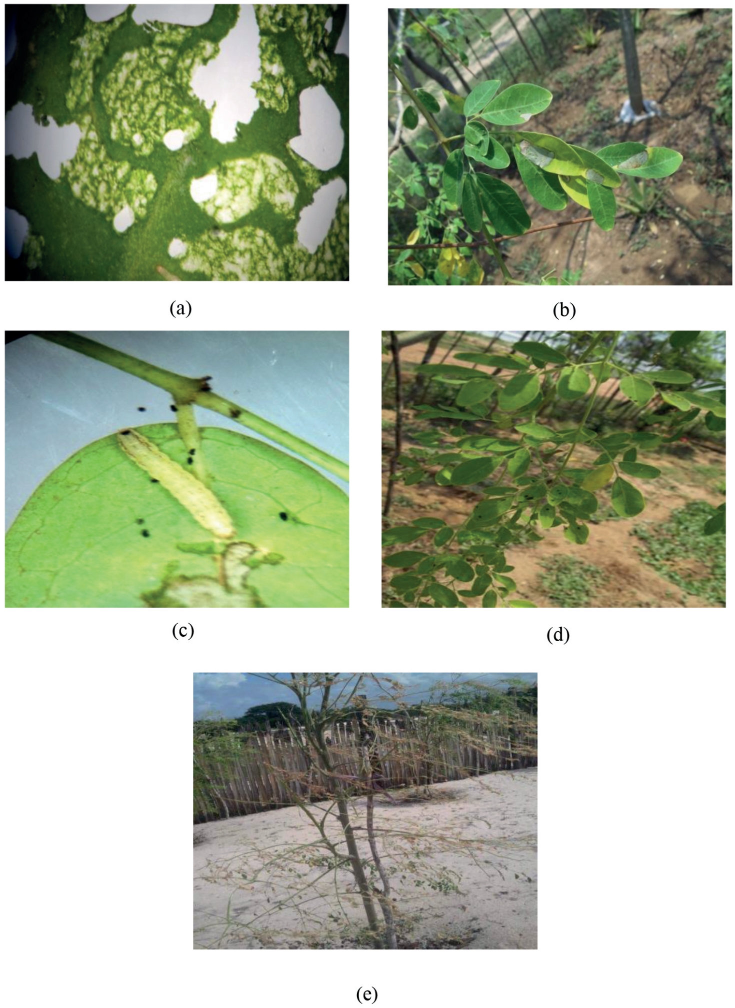

Figure 3: Damaged symptoms of *N. blitealis* [(a): Larva in the enrolled leaf, (b): Dried up leaves, (c): Faecal material of the larva, (d): Larva feeding on the ventral surface of the leaf, (e): Defoliated plant]

The survey revealed that, *Moringa* cultivators adapted chemical treatment (32%), hand picking (84%), purring (92%), sanitary measures (92%) and applied cow urine (16%), leaf extracts such as *Azadirachta indica* and *Gliricidia sepium* extracts (25%) and ash (33%), whereas, 6% of the *Moringa* cultivators did not take any control measures against the pest. Around 68 % of the *Moringa* cultivators used non chemical method of treatments and 32% used chemical treatment to control the pest population. Among the *Moringa* cultivators 63% of the cultivators applied both inorganic and organic fertilizers, 27% applied only organic, 2% solely inorganic and 8% did not apply any fertilizers.

(a)

(b)

(c)

Figure 4: Damaged symptoms of *G. distigma* [(a): Maggots of *G. distingma*, (b): Damaged pods compared with a normal pod, (c): Infested pods on the *Moringa*]

The infestation severity of the pest for organic and inorganic fertilizations showed positive weak correlations of 0.10 and 0.40, respectively. Increased nitrogen, water and sugar content of the host plant might significantly influence the fecundity, survival and efficacy of food consumption by pest (Slansky, 1982).

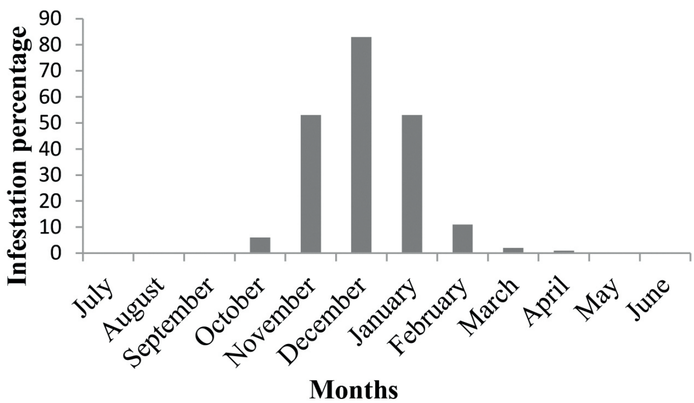

Figure 5: Infestation pattern of *N. blitealis* in a year

According to the survey, the plant spacing showed a negative weak correlation of 0.28 with the N. blitealis infestation. When the spacing between the plants decreased, the pest infestation was high, that is, in intensive cultivation the pest infestation was high.

There were many natural enemies associated with *N. blitealis* on *Moringa*. According to the survey, 98% of the fields had spiders predating on the larval stages of the pest. In addition there were *Chrysoperla carnea*, *Cydonia vicina*, mantis and a bird predator greater coucal (*Centropus sinensis*) predating on the pest. Spiders were observed as major predators of *N.blitealis*.

Conclusion

N. blitealis infestation was found in fourteen DS divisions and *G. distingma* was recorded in four DS divisions of the Jaffna District. Severe infestation of *N. blitealis* caused complete defoliation, hence death of the plant. *G. distingma* maggots fed on the flesh of the pods, which reduced the market quality of the pods. Pruning and sanitary measures were the common pest management practices in the home gardens. In the intensive cultivation, *N. blitealis* damage was recorded high. Home gardens harboured the natural predators of *N.blitealis*. Awareness of these pests should be created among the public in order to identify the pests and their damage for pest avoidance and management.

References

Anjaneyamurthy, J.N. and Reguoathy, A. 1992. Seasonal incidence of Moringa fruit fly (*Gitona* sp.) South India Horticulture. 40(1):43-48.

Bedane, T. M., Singh, S. K., Selvaraj, T., and Negeri, M. 2013. Distribution and damage status of moringa moth (*Noorda blitealis* Walker) on Moringa stenopetala Baker (Cufod.) in Southern Rift Valley of Ethiopia. Journal of Agricultural Technology, 9(4):963-985.

Fahey, J. W. 2005. Moringa oleifera: A Review of the Medical Evidence for Its Nutritional, Therapeutic, and Prophylactic Properties. Part 1. Trees for Life Journal. 1-13.

Morton, J.F. 1991. The horseradish tree, *Moringa pterygosperma* (Moringaceae) A boon to arid lands, Economic Botany, 45:318-333.

Satti, A. A., Nasr, O. E. H., Fadelmula, A., and Ali, F. E. 2013. New record and preliminary bio-ecological studies of the leaf caterpillar, *Noorda blitealis* Walker (Lepidoptera: Pyralidae) in Sudan. International Journal of Science & Nature, 4(1):57-62.

Slansky, F. 1982. Insect nutrition: An adoptionist's perspective, Florida Entomology, 65:45-71.

Journal of Dry Zone Agriculture, 2018, 4(2): 65 - 69

ISSN 2012-8673

Trends in Rainfall, Length of Growing Period and Drought Occurrence in Karnataka, India

Shivaramu, H. S.,[1] Venkatesh, H.,[2] and Padmashri, H. S.[3]

[1]*University of Agricultural Sciences, GKVK, Bangalore, Karnataka, India*
[2]*University of Agricultural Sciences, Dharwad, Karnataka, India*
[3]*University of Agricultural Sciences, GKVK, Bangalore, Karnataka, India*

Abstract: Climate has a vital role on biosphere of the earth. Of the major climatic parameters, rainfall is one of the most important parameters that influence the agriculture of the region and food production. A study was undertaken to analyze the trend of the rainfall pattern of Karnataka by using the daily rainfall data from 1980 to 2013 of 392 stations and its length of growing period (LGP) along with drought extent. Annual rainfall normals and rainy days normals over different stations was tested Mann-Kendall test was used for significance of trends in annual rainfall and annual rainy days. Also the frequencies of moderate and severe meteorological droughts were computed. Weekly values of precipitation and potential evapotranspiration were considered for computing length of the growing period. The mean annual rainfall of Karnataka in the last thirty three years was 1122±133 mm with a coefficient of variation (CV) of 12 %. Eighty two percent of the stations in the state shown no significant trend in annual rainfall while seventy one percent of the stations shown no significant trend in annual rainy days. Around 97% of the stations in the state show a probability of <10% of occurrence of severe droughts. Drought prone areas have been defined for Karnataka based on LGP concept. LGP varied between 168 days in Aland Taluk of Kalburagi district to 259 days in Beltangadi taluk of Dakshina Kannada district. According to LGP, agro-climatic zones of Karnataka have been re-delineated into new sub zones.

Keywords: Agro-ecological zones, drought, global warming, length of growing period, trends in rainfall

Introduction

Global climate change and its impact on agriculture is becoming an important issue even at the village level to meet the future food requirement at the regional level. The entire habitat of vegetation of an area depends on a

Corresponding author: H.S. Shivaramu, e-mail: *bng.aicrpam@gmail.com*

particular climate and they are accustomed to that. The major climatic parameters are rainfall, temperature, sunshine hours, relative humidity, wind speed etc., of which rainfall was one of the important factors. Rainfall has greater significance on agriculture of the region and food production, especially under Indian conditions, in general, Karnataka in particular.

Agriculture plays a vital role in Karnataka's economy. Agriculture and allied sectors account for about 13% of the Gross State Domestic Product (GSDP) and is among the top three contributors. About 57% of the total households in the State depend upon agriculture as their principal livelihood. About 61% of the total population lives in rural areas and 76% of them have small and marginal farm holdings. The average size of holding has decreased from 3.20 ha (1970-71) to 1.55 ha (2010-11), which is far less than the required economic size of 2.56 ha for Karnataka. Though cultivable area is around 64% (121.61 lakh ha.), only 33% area is under irrigation. Karnataka is second highest drought prone area next to Rajasthan. Due to the inherent nature of high temporal and spatial variability of rainfall in the state, it is important to have in-depth rainfall analysis. With an hypothesis that changing rainfall scenario could contribute to change in agriculture scenario, we have made an attempt to understand, if there exists any significant trend in rainfall, length of growing period (LGP) and drought behavior.

Materials and Methods

Daily rainfall data were collected from different sources like National Data Centre (IMD) and Department of Economics and Statistics (Government of Karnataka) for rain gauge stations working under their control. To work out a reasonable balance between lengths of data, number of stations, as well as making it up to most recent, the data period 1980-2013 for 392 stations were considered for the analysis.

We have made an attempt to calculate annual rainfall normal's and rainy days normal's over different stations. Kendall (1975) developed a procedure to test the trend and named it as Mann-Kendall test. The Mann-Kendall test reliably identifies monotonic linear and nonlinear trends with outliers. This test does not require normally distributed data and is well suited for analyzing datasets that have missing or tied data (Gilbert, 1987). Here we have used the same test to check the significance of trends in annual rainfall and annual rainy days.

Information on LGP helps in the selection of suitable crops, cropping systems, and crop cultivars as it reflect the period of congenial moisture availability. The LGP in any given region represents the climatically determined number of days during which a crop receives enough moisture from soil for its growth. As per the method proposed by agro-ecological zones project of the Food and Agriculture Organization of the UN, LGP was calculated as the period (in days) during a year when precipitation exceeds half the potential evapotranspiration (PET) (Higgins and Kassam, 1981). Weekly values of precipitation and PET were considered for computing LGP for all the taluks in Karnataka.

The frequencies of moderate and severe meteorological droughts were computed based on departures from normal annual rainfall in all taluks of Karnataka. As per IMD criteria, 26-50% deficiency was termed as moderate drought, and >50% was termed as severe meteorological drought.

Results and Discussion

Behavior of monsoons determines the availability of water for crops. Differences in commencement and end of monsoon result in the changes in length of growing period, which helps in choice of crops and their cultivars in about 64 % rain-fed area of the state. Therefore, the amount and distribution of rainfall during the crop growing season determines the productivity.

Annual rainfall of Karnataka

The mean annual rainfall of Karnataka in the last thirty three years was 1122 ± 133 mm with a coefficient of variation of 12 % (Venkatesh *et al*., 2016). Essentially, major part of the state possesses rainy days fewer than 50. The mean annual rainfall and rainy days distribution over the state is depicted in Figure 1 and Figure 2, respectively. Karnataka was divided into three meteorological sub-divisions such as North Interior Karnataka, South Interior Karnataka and Coastal. During the period of 1980-2013, inter-annual variability has been greater during the past 15 years in interior Karnataka in the period of analysis. Trends of rainfall and rainy days are almost the same.

Trends in annual rainfall and rainy days

The significance of the trends resulted from Mann Kendall test is presented in Figure 3 for annual rainfall and in Figure 4 for annual rainy days. 82 % of the stations in the state showed no significant trend (322 stations) in annual rainfall while 71 % showed no significant change (279 stations) with respect to annual rainy days.

Annual rainfall: Of the remaining 70 stations, 51 stations showed positive trend (13% of total stations), while 19 stations negative trend (6% of total stations).

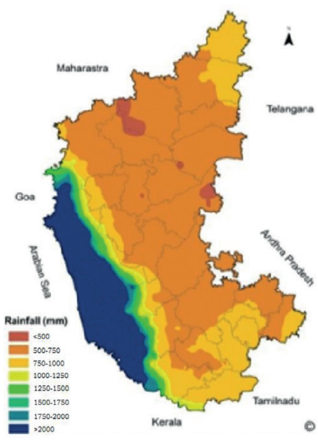

Figure 1: Annual rainfall in Karnataka

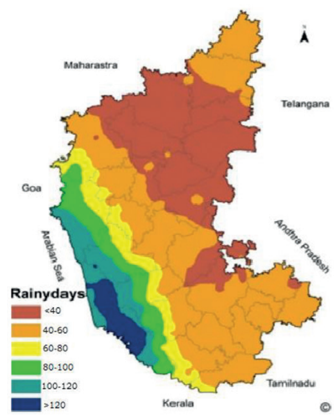

Figure 2: Annual rainy days in Karnataka

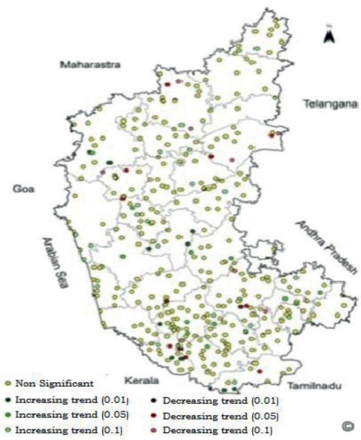

Figure 3: Trends in annual rainfall in Karnataka

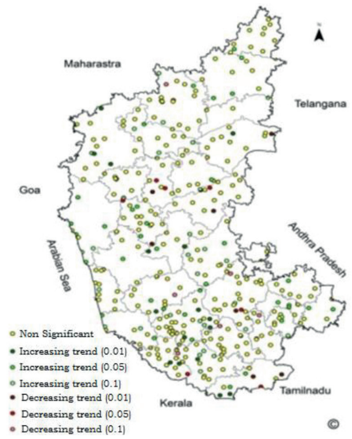

Figure 4: Trends in annual rainy days in Karnataka

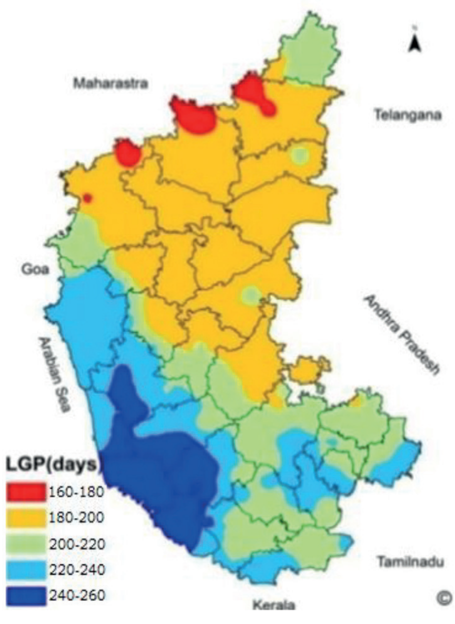

Figure 5: Length of growing period (LGP) in Karnataka

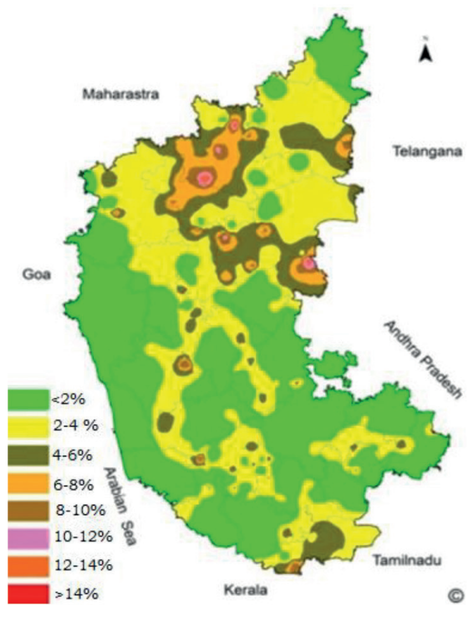

Figure 6: Probability of occurrence of severe meteorological drought in Karnataka

Out of the stations with positive trend, 50 % showed significance at 10 per cent, 28 % shown significance at 5 per cent and 22 % stations shown significance at 1 per cent. This indicates that the increasing trend was slower at 50 % of stations (PT-10%), and it was greater at other stations (PT- 5% & 1%). Out of the stations with negative trend, 38%

shown significance at 10%, 48% of stations shown significance at 5% and 14% of stations shown significance at 1 per cent. Thus, the negative trend observed was greater at more number of stations.

Annual rainy days: Of the remaining 113 stations, 89 stations showed positive trend (23% of total stations), while 24 stations showed negative trend (6% of total stations) for annual rainy days. An interesting point was noticed during the north east monsoon that none of the stations showed decreasing trend in annual rainy days while only 9% of the stations showed increasing trend indicating the shift in the wetness in October, November and December.

Length of growing period (LGP)

The spatial distribution of LGP is depicted in Figure 5. The length of growing period varies between 168 days in Aland Taluk of Kalburagi district to 259 days in Beltangadi taluk of Dakshina Kannada district. Fifty one %of taluks (88) in Karnataka has LGP between 180-210 days, and 31% of taluks (54) has LGP between 210-240 days.

While 13% of taluks (22) have LGP of more than 240 days (all are located in south Karnataka). According to LGP, the Karnataka has been delineated into agro-climatic zones and sub zones. There are ten agro-climatic zones in Karnataka, each having 2-4 sub zones divided based on LGP.

Meteorological drought

Meteorological drought occurs in all climatic regions of Karnataka, but its intensity differs from region to region. Around 97% of the stations in the state showed probability of < 10% of occurrence of severe droughts (Figure 6). The remaining three % of stations come in the category of 10-20% probability. Drought prone areas have been defined for Karnataka based on LGP concept (Naidu *et al*., 2003).

Conclusion

Recently, real time drought occurrence and drought affected areas are being announced for the state of Karnataka based on the rainfall deficiency and LGP based indices developed. Trends noted and present LGP becomes the base for re-delineation of present agro-climatic zones of Karnataka into new sub zones.

References

Gilbert, R.O. 1987. Statistical methods for environmental pollution monitoring, New York, Van Nostrand Reinhold.

Higgins, G. M. and Kassam, A. K.1981. FAO- Agro ecological zone approach for determining of land potential. Pedologie, 31 (2): 147-168.

Kendall, M. G. 1975. Rank correlation methods, 4th Ed., Charles Griffin Publishers London.

Naidu, L.G.K., Ramamurthy, U., Rajendra Hedge, Challa, O., Krishnan, P. and Gajbhiye, K.S. 2003. Soil site suitability criteria for major crops, NBSS & LUP Technical Report -582.

Venkatesh, H., Rajegowda, M. B., Shivaramu, H. S. and Rao, V. U. M. 2016. Agroclimatic atlas of Karnataka, All India Coordinated Research Project on Agrometeorology, Vijayapura and Bengaluru, UAS Dharwad Publishing.

Journal of Dry Zone Agriculture, 2018, 4(2): 70 - 74

ISSN 2012-8673

Growth and Yield Response of Mechanical Transplanted Rice at Different Plant Densities

Sivaneson, S. and Vijayakumari, V

Rice Research Station, Paranthan, Kilinochchi, Sri Lanka

Abstract: Optimum plant spacing is among key agronomic parameters that influence on growth and yield in rice (*Oryza sativa* L.). A field experiment was conducted to evaluate the growth and yield response of mechanical transplanted rice at the Rice Research Station, Paranthan during *Maha* season, 2016/17. The machine transplanting method considered as practical option to minimize the labor usage with the timeliness cultivation of rice. Recent past, rice transplanter was introduced to paddy farmers of Kilinochchi district by the governmentof Sri Lanka. However, adaptation of this method is still low due to socio-economic background and lack of technical information. Four rows of man-propelled paddy KUBOTA (SPW 48c) transplanter was used in this study with 30cm row spacing (non-adjustable) and 5 within row spacing levels (12, 14, 16, 18 and 21 cm), replicated four times in each. The rice variety Co-10 was used with the plot size of 4m×6m. The plant height, number of tillers at different stages, percentage of canopy coverage and yield components such as panicle per hill, panicle length, grain yield and 1000 grains weight were recorded. Results revealed that the spacing of 30cm×16 cm produced significantly higher number of tillers and panicles than others. The spacing of 30cm×16 cm recorded the highest (p<0.05) percentage of canopy coverage (75 %), 1000 grain weight (24.9 g) and grain yield (7921.9 kg/ha). This study concluded that spacing of 30cm×16cm can be considered as optimum plant density for machine transplanted rice for the variety Co-10 compared to other tested spacing in this region.

Keywords: Canopy coverage, growth, mechanical transplanting, rice, spacing, yield

Introduction

Rice (*Oryza sativa* L.) is a staple cereal crop for more than half of the world's population. The ever-increasing population demands rapid increase in rice productivity to ensure global food security (Chauhan *et al*., 2011; Abid *et al*., 2015). Paddy occupies nearly 15 percent of arable lands (820,000 ha) in Sri Lanka. Direct seeding, which is the common method of rice establishment gives a lower

Corresponding author: S. Sivaneson, e-mail: *ssivaneson@yahoo.com*

yield compared to transplanting. Although conventional transplanting gives a uniform crop stand, it is quite expensive and requires more labor days besides involving lot of drudgery. Singh *et al*. (1985) reported that transplanting takes about 250-300 man hours/ha which is roughly 25 per cent of the total labor requirement of the crop. Further, along with rapid industrialization and migration to urban areas, the availability of labor became very scarce. As it hike the labor wages, manual transplanting found costly leading to reduced profits to farmers. In general, the cultivation time ranges from three to six months, depending upon the selected rice varieties and the seasons when crops are cultivated. Growth and yields of rice are sensitive much on variability of land preparation, climatic conditions, proper care, and water supplies. Thus, improper farming techniques may obviously lead to a waste of invested capital and low outcomes. Since rice cultivation requires a great deal of available labor, lack of man-power may lead to late farming or little care which signifies a pressing need for machine aid to boost crop production (ADB, 2014). Mechanical transplanting of rice has been considered as a promising technique to increase rice productivity through labor saving, timely transplanting, archiving optimum plant density in the field, and cutting down unnecessary labor use. A rice transplanter was introduced by the government recently to encourage farmers to adopt this technology. Therefore, this study was aimed to determine the suitable mechanical transplanting spacing promoting rice growth and increasing rice yield.

Materials and Methods

The experiment was carried out at Rice Research Station, Paranthan during *Maha* 2016/2017. The experimental site receives an average rainfall of 750 mm and average temperatures 28.4-34.5 °C (max) and 19.7-24 °C (min). The aim of this study was to find out the optimum plant density to the better performance of yield for mechanically transplanted rice. Five within row spacing levels such as30cm×12cm (T1), 30cm×14cm (T2), 30cm×16cm (T3), 30cm×18cm (T4) and 30cm×21cm (T5) were tested. The experiment was laid in a Randomized Complete Block Design with four replicates in each spacing level. The plot size was 6m×4m. Rice variety, Co-10 was selected as is it performed well in transplanted rice during the previous season. Seedlings were raised in a dapog nursery to use in mechanical transplanting. Pre-germinated seeds were spread uniformly in a tray filled using equal quantities of soil and farm yard manures. Seedlings of 2-3 leaf stage (15 days) were fed to transplanter. The man-propelled paddy KUBOTA (SPW 48c) transplanter with four rows was used for planting 3-4 seedlings per hill throughout the treatments on 8th December 2016. This machine has the adjustment for changing hill spacing (within row spacing-WRS) and row width (between rows) is 30 cm non-adjustable. All agronomic practices for rice were done according to guidelines given by Department of Agriculture (2013).

Data collection

The observations were recorded on plant height (cm), number of tillers, panicle length (cm), number of panicles per plant, percentage of canopy coverage, thousand (1000) grains weight (g), fertile tillers per plant, panicle length and grain yield per plot (kg). Percentage canopy coverage was measured by using Line Intercept Method (Canfield, 1941).

Percentage of canopy cover of rice=

$$\frac{\text{total distance of rice covered by rice canopy}\times 100}{\text{total distance of line}}$$

Data analysis

The collected data were subjected to ANOVA using software SAS (version 9.1). Significant means were separated using the Duncan's Multiple Range Test (DMRT) at $\alpha \leq 0.05$.

Results and Discussion

Plant height

Plant height (cm) measured at three growth stages (Table 1) varied significantly ($p<0.05$) with different densities. Maximum plant height (95.04 cm) recorded in the treatment 5 (30cm×21cm) could be due to less competiveness among plants for absorbing water and nutrition.

Similar results shown that the widest spacing might be attributed to maximum utilization of light, water and other inputs to produce and then translocate photo-assimilates into sink (Khaliq *et al*., 2011). Minimum plant height (88.04 cm) was recorded in the treatment 4 (30cm×18cm). At vegetative stage, plant heights were not significantly differed among densities. Similar results found in mechanically transplanted rice to increase their leaf biomass during the vegetative period irrespective to within row space (Illangkoon *et al*., 2017).

Number of tillers per hill and panicle number per hill

The number of tillers produced per hill under the different spacing adopted is presented in Table 2. The number of tillers per hill produced significantly ($p<0.05$) differed among densities. A positive correlation was observed between densities and tillers per hill. However, the number of tillers produced per m^2 decreased with increased densities (T5). The maximum number of tillers per hill and panicle numbers per hill were recorded from the treatment 3 (30 cm ×16 cm spacing). Illangkoon *et al*. (2017) reported that a negative correlation between within raw space and tillers/m^2. Lowest number of productive tillers and panicle numbers per hill were observed in the plant spacing 30cm×18cm (T4).

Figure 1: Taking measurement of canopy coverage

Table 1: Plant height (cm) at different growth stages

Treatment	Vegetative stage	Reproductive stage	Harvesting stage
T1 (30cm ×12cm)	44.46[a]	70.13[c]	90.08[b]
T2(30cm × 14cm)	42.79[a]	77.46[ab]	90.25[b]
T3(30cm × 16cm)	44.63[a]	75.71[b]	92.75[ab]
T4(30cm × 18cm)	43.13[a]	80.33[a]	88.04[b]
T5(30cm × 21cm)	45.71[a]	80.83[a]	95.04[a]

The numbers not sharing a letter in common in the same column, differed significantly at $p< 0.05$

Percentage of canopy coverage

The maximum plant canopy coverage (75 %) was recorded in treatment 3 (30cm×16cm spacing) and it was significantly higher than others. In addition, visual observation showed a less weed population in the same (T3) treatment and it could be due to high canopy coverage.

Panicle Length (cm)

Data on panicle length (Table 2) revealed that treatment 5 (30cm×21cm) had significantly higher panicle length (22.46 cm) compared to the rest. Similar results showed that the increased plant spacing, the effects on panicle density and grain yield were significantly high (p<0.01) (Baloch *et al*., 2002). The treatment 2 (30cm×14cm) showed the lowest (20.83 cm) panicle length.

Thousand-grain weight (g)

Thousand-grain weight, an important yield-determining component, is a genetic character least influenced by environment (Ashraf *et al*., 1999). The plant density showed significant ($p<0.05$) effect on 1000 grains weight. Higher 1000 grains weight (24.90 g) was recorded in treatment 3 and lower grain weight (22.70 g) recorded in treatment 1.

Grain yield

The effect of spacing on grain yield is presented in Table 2. Grain yield was significantly influenced by the plant density. Grain yield was high in treatment 3 (16cm×30cm) followed by treatment 1. Highest performance in grain yield could be due to an optimum

Table 2: Analysis of variance under different levels of spacing

Treatment	Tiller Numbers per hill	Percentage of Canopy Cover	Panicle Number per hill	Panicle length (cm)	Yield (kg/ plot)	Yield (kg/ha)	1000 seeds weight(g)
T1	14.00[b]	70.63[ab]	13.21[b]	20.92[b]	17.34[ab]	7224.0[ab]	22.70[c]
T2	12.13[c]	68.75[ab]	11.25[c]	20.83[b]	13.89 [b]	5786.5[b]	24.53[ab]
T3	17.42[a]	75.31[a]	16.54[a]	20.88[b]	19.01[a]	7921.9[a]	24.90[a]
T4	11.83[c]	59.06[b]	10.54[c]	21.67[ab]	12.88[b]	5364.6[b]	23.43[bc]
T5	14.96[b]	72.06[b]	12.92[b]	22.46[a]	14.28[b]	5947.9[b]	24.05[abc]

The numbers not sharing a letter in common in the same column, differ significantly at $p< 0.05$

condition for light reception, less competition for nutrient consumption and thereby the high accumulation of photosynthates in grains. The lowest yield (5364.6 kg/ha) was recorded inT4.

Conclusion

This study concluded that planting space can play a vital role to increased rice yield under mechanical transplanting system. The spacing of 30cm×16cm produced 8.7% higher yield than the yield at 30 cm ×12 cm spacing. Highest canopy coverage was also recorded at 30cm×16cm spacing showing the visible increase in weed suppression capacity. The results on this single season experiment revealed that 30cm×16cm row-hill spacing can be successfully used for high yielding Co-10 red pericarp rice under mechanical transplanting system. However, this research needs further validation.

References

Abid, M., Mahmood, F., Ashraf, U., Imran, M. and Anjum, S. A. 2015. Response of hybrid rice to various transplanting dates and nitrogen application rates. Philippine Agricultural Scientist, 98:98-04.

ADB (Asian Development Bank). 2014. Improving rice production and commercialization in Cambodia: Finding from a farm investment climate assessment. Mandaluyong City, Philippines.

Ashraf, A., Khalid, A and Ali, K. 1999. Effect of seedling age and density on growth and yield of rice in saline soil. Pakistan Journal of Biological Sciences, 2(30):860–862.

Baloch, A.W., Soomro, A.M., Javed, M.A., Ahmed, M., Bughio, H.R., Bughio, M.S. and Mastoi, N.N. 2002.Optimum plant density for high yield in rice (Oryza sativa L.). Asian Journal of Plant Sciences, 1(1):25-27.

Canfield, R.H. 1941. Application of the line interception method in sampling range vegetation. Journal of Forestry, 39:388-394.

Chauhan B.S. and Johnson, D.E. 2011. Row spacing and weed control timing affect yield of aerobic rice. Field Crops Research, 121: 226-31.

Illangkoon. T.K., Somaratne, J.M.N.P., Keerthisena, R.S.K., Abeysundara, M.D., Piyasiri, C.H. and Kumar, V. 2017. Impact of varieties, spacing and seedling management on growth and yield of mechanically transplanted rice, Annals of Sri Lanka Department of Agriculture, 19: 112 – 128.

Khaliq A., Riaz, M. Y. and Matloob, A. 2011. Bio-economic assessment of chemical and non-chemical weed management strategies in dry seeded fine rice (*Oryza sativa* L.). Journal of Plant Breeding and Crop Sciences, 3:302-10.

Singh, G., Sharma, T. R. and Bock hop, C. W. 1985. Field performance evaluation of a manual rice transplanter. Journal of Agricultural Engineering Research, 32: 259-268.

Journal of Dry Zone Agriculture, 2018, 4(2): 75 - 83

ISSN 2012-8673

Determinants of Herbicide Use in Rice Production Systems of Sri Lanka

Munaweera, T.P. and Jayasinghe, J.A.U.P.

Hector Kobbekaduwa Agrarian Research and Training Institute, Colombo, Sri Lanka

Abstract: This study identifies farm-specific and market factors affecting the adoption of herbicides and the level of herbicide use by rice farmers in Sri Lanka. Determinants of adoption and level of herbicide use were explored using a comprehensive data set collected from 240 randomly selected paddy farmers from selected areas in the Anuradhapura, Ampara, Matara and Kurunegala districts. Study employed the cross sectional Double Hurdle model that describe demand decisions on herbicides arising from two hurdles that have to be overcome for positive demand. Household size, farming experience, type of irrigation, training received related to pest control and extent under cultivation were significant determinants of the decision of farmers to adopt herbicide as an alternative to manual weeding, while, age, sex, extent cultivated, farm gate price, tenurial status, type of irrigation and training related to pest control determine the quantity of herbicide use. Findings highlight the complexity of the issue, hence the institutions seeking to avoid the overuse of herbicide or to encourage adoption of alternative methods of weed control are likely to need to use multiple strategies to address the key variables. The insights generated should be of value to agricultural extension officers, researchers and policy makers. These results are potentially relevant when designing policies to reduce excessive herbicide use or to encourage the adoption of alternative weed control methods such as integrated weed management.

Keywords: adoption, Double-Hurdle model, herbicide, rice

Introduction

Rice cultivation is being challenged by multiple pests and weed considered as the major biotic stress that reducing 30 – 40 percent of rice yield (Abeysekara, 2001). Therefore, proper and effective weed management techniques are utmost important to acquire better yield from almost all areas of rice producing in Sri Lanka. Traditionally, weed management in rice mainly done through water management

Corresponding author: T.P. Munaweera, e-mail: *thilanimunaweera@gmail.com*

and manual weeding. However, herbicide application has increased significantly over last decades mainly due to free availability of herbicides in the market at lower prices, water scarcities and labour shortages (Beltran *et al*, 2013). Weed control using herbicides is the most popular method among farmers nowadays and it allows economically viable weed control providing cost-effective method in the production of agricultural crops. On the other hand, rice cultivation method has shifted from transplanting to direct seeding and herbicide application become a must under this system because under direct seeding difficult to control weed growth by flooding. This has led farmers to apply herbicides indiscriminately creating many negative externalities. Even though the negative externalities associated with pesticides are obvious, farmers use herbicides at increasing trend because marginal increase in pesticide use still appears to be profitable to farmers compared with other alternative weed control methods (Damalas, 2009).

Even though many technical studies have been conducted to find out the chemical properties and pesticide residues in water bodies and food commodities, there are few recent studies on socio-economic aspects of herbicide use in the country. Therefore, this study was designed to analyse the economic and noneconomic determinants of the adoption and level of herbicide use decisions on Sri Lankan rice farms. The investigation of these factors contributes to understanding the factors that motivate the use of herbicides and thus how institutions can further develop appropriate farm programs and projects to promote sustainable agricultural practices while reducing incidence of herbicides misuse. With that background, the objective of this study is to analyse the determinants of the adoption and level of herbicides use decisions on Sri Lankan rice farmers.

Materials and Methods

Cross sectional data for the study were collected from 240 randomly selected rice farmers from selected areas in the Anuradhapura, Ampara, Matara and Kurunegala districts. Above four districts selected based on the total area under paddy cultivation and to represent the three main agro-ecological regions, dry zone, wet zone and intermediate zone. To evaluate the objectives of the study, sample farmers were interviewed personally using a pre-tested structured questionnaire. Among sample farmers, some are using herbicides and some are not using chemical herbicides. In addition, there are differences in level of usage (quantity applied) for unit land area among the users. Literature suggests that farmers' decision to adopt a new technology can be modelled using several theoretical frameworks (Awotide *et al*, 2014). However, many of the numerous studies that assessed the determinants of farmers' adaptation to new agricultural technology have employed the Logit, Probit or Linear probability models. The Tobit model (Tobin, 1958) was the original and most commonly used model to analyze the functions with zero dependant variable values. However, one of the major drawbacks of the Tobit model is that the decision on whether to adopt or not and how much to adopt are assumed to be made jointly and assume that zero expenditure is attributable to economic factors alone (Newman *et al*, 2003). Several empirical studies (Blundell and Meghir, 1987; Blaylock and Blisard, 1993; Garcia and Labeaga, 1996; Yen and Jones, 1996) have shown the inadequacy of the standard Tobit model in cross sectional analysis of adoption, connected with its failure in accounting for differences concerning the generation of zero observations. Firstly, the possibility of occurring zero observation due to non-participation in the market for non-economic reasons were modelled in double hurdle model. In other words, in double hurdle model non-adopters are considered as a corner solution in a utility maximization model (Mal *et al.*, 2012).

Thus, in this paper herbicide usage in rice cultivation was investigated by using Cragg's (1971) Double Hurdle (DH) model by addressing the issues connected to limited dependent variable models. As discussed basic property of this bivariate decision model is that it models the zero value of application of herbicides as a decision result. According to the model, a farmer faces two hurdles while deciding on herbicide application. First hurdle decide whether to use herbicide to control weeds in rice fields. The second hurdle is related to the level of adoption, or what quantity of herbicides to apply. In particular, it postulates that each individual must pass two separate hurdles before they are observed with a positive level of usage. The first hurdle corresponds to factors affecting the decision of using or not using the chemical herbicides and the second to the level of application of the herbicides.

The first hurdle is estimated using Probit model to determine the participation and second hurdle use Tobit model to determine the level of usage (Blundell and Meghir, 1987).

The two decision processes can be formalized as;
The participation decision:

$$d_i^* = \alpha w_i + v_i \qquad (1)$$

The consumption decision:

$$y_i^* = \beta x_i + u_i \qquad (2)$$

Where d_i^* is the latent discrete variable that represents the pesticide application choice that denotes binary censoring, w_i is the vector of explanatory variables hypothesized to influence pesticide application choice, y_i^* is the latent variable describing the level of pesticide application, x_i vector of variables explaining the quantity of pesticide applied and α and β are vector of parameters to be estimated. v_i and u_i are the standard error term. y_i and d_i are the observed counterparts. Observed variable relate to latent variable such that,

$$d_i = \begin{cases} 1, if\ d_i^* > 0 \\ 0, if\ d_i^* \leq 0 \end{cases} and\ y_i =$$

$$\left\{\begin{matrix} y_i^*, if\ y_i > and\ d_i^* > 0 \\ 0, if\ otherwise \end{matrix}\right\} \qquad (3)$$

The dependent variable in the first stage is the farmer's adoption decision (i.e. decision on using or not using pesticides). This variable is binary in nature, taking numeric value 1 for pesticide users, and 0 for non-users. di is the observed quantity of pesticides representing the respondents' participation decision (i.e. 1 means the respondent is reporting pesticide application greater than 0, and 0 means no chemical pesticide application is reported). The second hurdle involves an outcome equation, which uses truncated model to determine the intensity of pesticide application. This equation uses observations only from farming households who reported positive uses of chemical pesticides. In the second stage, the dependent variable is the amount of pesticide applied. As the variables explaining adoption can also explain the level of adoption (or amount of pesticide applied), the same set of independent variables can be used in both stages. The list of explanatory variables is given in Table 1.

According to Carroll, McCarthy and Carol (2005), equations 1 and 2 are assumed independent, and therefore error terms are randomly and independently distributed as equation 4.

$$\begin{Bmatrix} v_i \sim N(0,1) \\ u_i \sim N(0,\sigma^2) \end{Bmatrix} \tag{4}$$

With the above error term assumptions, the likelihood equation becomes (Burke, 2009; Cragg, 1971)

$$L_i = [1-\Phi(\alpha' w_i)]^{1(d_i=0)} * \left[\frac{\frac{1}{\sigma_i}\varphi\left(\frac{y_i-\beta' x_i}{\sigma_i}\right)\Phi(\alpha' w_i)}{\Phi\left(\frac{\beta' x_i}{\sigma_i}\right)} \right]^{1(d_i=1)} \tag{5}$$

If no separate first hurdle exists, everyone is assumed as pesticide users, i.e. $\Phi(\alpha' w_i)= 1\forall_i$ and the model reduced to the Tobit model. Herbicide adoption and demand was analysed separately for two main rice cultivation seasons 2014/2015 *Maha* and 2015 *Yala* season. Factors that determine the adoption of herbicides were analyzed using Tobit model and demand function was analyzed using Probit model using Cragg's Double Hurdle Model approach. General description of the variables used in econometric analysis is presented in table 1.

In adoption model, a discrete latent variable of herbicide use (*adopth*) take a value of 1 if the farmer sprayed with chemical herbicides and 0 if farmer does not use herbicide during the considered cultivation season. In the herbicide use model, latent variable the amount of herbicide active ingredients used per acre of land (*uaih*) used as dependant variable.

Results and Discussion

A positive significant coefficient in the first hurdle Probit model signifies that the corresponding regressor increases the probability of a positive observation in the adoption process. Similarly, in the second hurdle, a positive coefficient means that conditional on a positive of the used amount. Results for the adoption demand models were significant at the 0.01 percent level based on a model Chi square statistics. Significant log-likelihood and LR Chi-square values imply that the model is fitted well and the explanatory variables used in the mode are collectively able to explain the level and determinants of herbicide adoption.

Table 1: Variable description

Variable	Description
Dependant variable	
adopthm	Value 1 if farmers use herbicides in *Maha* season, 0 otherwise
adopyhy	Value 1 if farmers use herbicides in *Yala* season, 0 otherwise
uaihm	Unit herbicide active ingredients in *Maha* season
uaihy	Unit herbicide active ingredients in *Yala* season
Independent variable	
Labour and human capital	
age	Age of the farmer (years)
sex	Value 1 if female, 0 otherwise
fexp	Number of years in rice farming
hhsize	Number of total household members
prempl	Value 1 if full time farmer, 0 otherwise
training	Value 1 if attended training on pest control, 0 otherwise
educ	Number of years in school
Land characteristics	
tstat	Value 1 if farmer owns a farm, 0 otherwise
extyala	Extent cultivated in *Yala* season
extmaha	Extent cultivated in *Maha* season
Infrastructure	
irrig	Value 1if irrigated, 0 otherwise
Type of technology	
seedty	Value 1 if certified seeds, 0 otherwise
plantigm	Value 1 if transplanting, 0 direct seeding in *Maha* season
plantigy	Value 1 if transplanting, 0 direct seeding in *Yala* season
Economic variables	
mahaprice	Farm gate price *Maha* season
yalaprice	Farm gate price *Yala* season
District dummy	
ampara	Value 1 if Ampara district, 0 otherwise
kurun	Value 1 if Kurunegala district, 0 otherwise
matara	Value 1 if Matara district, 0 otherwise

Estimated results for Double Hurdle model allied to *Maha* season presented in the table 2 and table 3 shows the estimates related to *Yala* season. Family size, farming experience, type of irrigation, training received related to pest control, extent under cultivation were recorded as significant determinants of the farmers' decision in adopting herbicide use, while factors; age, sex, extent cultivated, farm gate price, tenurial status, type of irrigation and training related to pest control determine the quantity of herbicide use.

Household size only significant in adoption model, hence this implies that farmers with larger family size are more likely to adopt herbicides for controlling weeds, but once the farmers decided to use herbicides, their decision regarding the quantity of herbicides to be applied are not affected by household size. Type of irrigation significantly affects adoption and it highlights the importance of water as a determinant of chemical use. Application of herbicides is more effective if water is controlled and positive sign of the coefficient indicate that irrigated farmers apply more chemicals than rainfed farmers. According to the adoption model, results access to formal source of information also affect on the decision of herbicide use. Negative and significant relationship between age and quantity of active ingredient applied indicates that older the farmer lower the level of herbicides applied. Negative and significant relationship of variable sex denotes that female farmers apply lower active ingredients of herbicides than male farmers.

Table 2: Probit and Tobit parameter estimates of herbicide use in *Maha* Season

Variable	Adoption (Probit model)		Herbicide a.i. (Tobit model)	
	Coefficient	S.E.	Coefficient	S.E.
cons	2.461*	1.302	575.851	300.224
age	-0.025	0.020	-5.280*	4.053
sex	-0.289	0.437	-159.268**	85.318
fexper	0.017	0.019	4.268	3.677
hhsize	-0.182***	0.074	-21.298*	15.971
educ	-0.039	0.036	-4.498	7.217
extmaha	0.119	0.077	16.916*	12.055
mahaprice			10.309***	3.825
tstat			-165.771**	85.133
plantigm			-76.122	115.509
prempl	0.184	0.366	-40.943	82.098
seedty	-0.063	0.295	-123.56**	60.944
training	-0.137	0.290	87.263*	59.903
irrg	0.571**	0.285	175.405***	60.520
info	0.828***	0.292	5.559	59.434
ampara	0.592	0.452	157.213**	83.214
kurun	-0.101	0.358	-40.825	84.534
matara	1.209***	0.517	-8.581	97.934
LR (chi 2)	30.40		54.26	
Log likelihood	-58.566		-1583.689	
Pseudo R2	0.206		0.017	

***significance at 1%, **significance at 5%, *significance at 10% levels. S.E. = Standard Error

This could be due to female farmers are more likely to use hand weeding than chemical application. Of the land characteristics variables, tenurial status (*tstat*), and cultivated extent significantly affect herbicide quantity. Negative sign of variable tenurial status indicate farmers who own their farm are less likely to use herbicides.

Positive and significant relationship of variable extent under cultivate in demand model implies that with the increase of cultivating land amount of active ingredient applied for unit area is also increasing.

Table 3: Probit and Tobit parameter estimates of herbicide use in *Yala* Season

Variable	Adoption (Probit model)		Herbicide a.i. (Tobit model)	
	Coefficient	SE	Coefficient	SE
cons	1.566	1.177	124.882**	343.326
age	-0.013	0.018	-7.572*	4.743
sex	-0.571	0.422	-243.29***	100.541
fexper	0.014	0.016	8.504**	4.312
hhsize	-0.113*	0.065	-3.713	18.595
educ	-0.017	0.031	-9.263	8.448
extyala	0.379***	0.103	26.983**	15.145
yalaprice			14.940***	3.208
tstat	-0.627	0.490	-150.716*	101.166
plantigy			-129.932	133.099
prempl	0.513	0.328	73.311	99.516
seedty	-0.001	0.258	-56.998	72.454
training	0.053	0.252	118.098**	71.210
irrg	0.781***	0.263	247.349***	74.539
info	0.404	0.262	88.356	71.596
ampara	0.183	0.360	233.228***	98.403
kurun	0.173	0.335	187.124**	98.895
matara	1.240***	0.440	288.173***	111.721
LR (chi 2)	58.86		80.92	
Log likelihood	-76.001		-1502.182	
Pseudo R2	0.279		0.026	

***significance at 1%, **significance at 5%, *significance at 10% levels. S.E. = Standard Error

Rice farm gate price also positively significant in demand model indicating that with high price farmers are more willing to invest on weed control methods to maximize their net income. Negative and significant values in age and sex variables in demand model suggests that older farmers and women farmers use less herbicides than young and male counterpart. With the increase of years with farming experience farmers tempt to use more quantities of herbicides according to the regression results and this is also ascertain by farmer responses to over using chemicals. Most of the farmers who are applying higher dosage than recommendation give the reason that with their past experience they know recommended dosage is not enough to control weed successfully.

Negative significant relationship of variable *seedty*, which represents the type of seeds used by the farmer suggests that farmers who are using certified seeds apply less herbicide. This implies that if seeds are not coming from certified source it may contain many impurities like weed seeds, hence need more herbicides to control weeds in the field. Participation in pest control related training has positive significant impact on herbicide quantity and this could arise because most of the training events related to pest control in rice cultivation are commonly sponsored and conducted by pesticide companies. Regional dummy variables for Matara, Kurunegala and Ampara show that region is a key determinant of herbicide use, but its impact is highly variable. These differences could be attributed to specific localized seasonal problems with crop weeds and prevailed climatic conditions etc.

Conclusions

This study examined the factors affecting the adoption and intensity of use of herbicides in Sri Lankan rice-farming systems. Investigation of these factors contributes to improved understanding of the factors that motivate the use of herbicides and factors that determine the quantity applied. Results broadly revealed differences in the key drivers of the adoption and use decisions. Household size, farming experience, type of irrigation, training received related to pest control extent under cultivation are the common variables that have significant effect on the decision on adopting or non-adopting the herbicides in the *Maha* and *Yala* seasons.

According to the Double Hurdle Model analysis, age, sex, extent cultivated, farm gate price, tenurial status, type of irrigation and training related to pest control were identified as common variables having impact on quantity of active ingredients of herbicides applied in both *Yala* and *Maha* seasons.

Finally, the findings of the study highlight the complexity of the issue, with different variables influencing farmer's decisions on whether to adopt herbicides at all, and if so how much herbicides to be used. Institutions intervening to regulate the herbicides use and/ or to encourage farmers to adopt alternative methods in weed control need to use multiple strategies to address the key variables. Further, the results are potentially relevant in designing policies to reduce excessive use of herbicides and to encourage adoption of alternatives.

References

Abeysekara, A.S.K. 2002. Management of Echinochloa spp. in rice in Sri Lanka. FAO workshop on Echinochloa spp. Control, Beijing, China. 2001; FAO Rice Information, 3:13.

Awotide, B., Abdoulaye, T., Alene, A., and Manyong, V. M. 2014. Assessing the extent and determinants of adoption of improved cassava varieties in southwestern Nigeria, Journal of Development and Agricultural Economics, 6(9): 376 – 385.

Beltran, J.C., White, B., Burton, M., Doole, G.J. and Pannell, D.J., 2013. Determinants of herbicide use in rice production in the Philippines, Agricultural Economics, 44(1): 45-55.

Blaylock, J.R. and Blisard, W.N. 1993. Wine consumption by US men, Applied Economics, 24: 645-651.

Blundell, R. and Meghir, C. 1987. Bivariate Alternatives to the Univariate Tobit Model, Journal of Econometrics, 34: 179-200.

Burke, W. J. 2009. Fitting and interpreting Cragg's tobit alternative using Stata, Stata Journal, 9(4): 584.

Carroll, J., McCarthy, S., and Newman, C. 2005. An econometric analysis of charitable donations in the Republic of Ireland, The Economic and Social Review, 36(3): 229-249.

Cragg, J. G. 1971. Some statistical models for limited dependent variables with application to the demand for durable goods, Econometrica - Journal of the Econometric Society, 39(5):829-844.

Damalas, C. A. 2009. Understanding benefits and risk of pesticide use, Scientific Research and Essays, 4:945 - 949.

Garcia, J. and Labeaga, J.M. 1996. Alternative Approaches to Modelling Zero Expenditure: An Application to Spanish Demand for Tobacco, Oxford Bulletin of Economics and Statistics, 58:489-506.

Mal, P., Anik, A.R., Bauer, S. and Schmitz, P.M. 2013. Bt cotton adoption: a double-hurdle approach for north Indian farmers, AgBioForum, 15(3):294-302.

Newman, C., Henchion, M. and Matthews, A. 2003. A double-hurdle model of Irish household expenditure on prepared meals. Applied Economics, 35(9):1053-1061.

Tobin, J. 1958. Estimation of relationships for limited dependent variables, Econometrica, 26:24-36.

Yen, S.T. and Jones, A.M. 1996. Individual Cigarette Consumption and Addiction: a Flexible Limited Dependent Variable Approach, Health Economics, 5:105-117.

Journal of Dry Zone Agriculture, 2018, 4(2): 84 - 89

ISSN 2012-8673

Root fouling organisms of *Rhizophora mucronata* in Rekawa Lagoon, Sri Lanka

Wanasuriya, W.M.A.P., Kumara, M.P. and Wijesundara, W.M.I.C.

Faculty of fisheries and Marine science, Ocean University of Sri Lanka, Mahawela Road, Tangalle, Sri Lanka

Abstract: Mangrove underwater roots provide habitats for a variety of root fouling organisms. Since there is a dearth of information locally on the fauna and flora growing on such habitats, a study was carried out to study the biodiversity of mangrove root fouling organisms at the Rekawa lagoon (05° 58' N and 80° 50' E). In this study, a mangrove prop root that is hanging freely into the water from each one of the 20 randomly selected *Rhizophora mucronata* trees was cut to collect the fouling organisms from four different zones, namely, the top most, upper middle, lower middle and near the bottom along the root. The number of solitary countable organisms were recorded per unit surface area (m-2) of each one of the four root zones. The abundance of the non-countable colony-forming organisms were determined using the % volume values following the points (volumetric) method. Abundance data were analyzed non-parametrically using the Kruskal Wallis test. Further, the diversity of organisms in each zone of the root were also calculated. Twenty seven different taxa of fouling organisms including countable taxa such as Isopods, Amphipods, Copepods, Polychaets, Bivalves, Heliozoans, Diatoms, *Oscillatoria* sp., Nematodes, Cryptophyta, Bacillariophyta, Phytoplankton, Foraminfera, Chlorellacea and colony forming non-countable taxa such as Rhodophyta, porifera, *Hydra* sp., Ascidiacea, *Ulothrix* sp., Ciliophora and Chlorophyta were recorded. The median abundance of countable organisms was significantly higher in the upper middle zone (2461 m^{-2}) than that in the bottom zone (1057 m^{-2}). Further, the median diversity of these fouling organisms in the upper middle zone was significantly higher (196 m^{-2}) than that in the bottom layer, which showed the minimum diversity (70.83 m^{-2}). However, the median % volume of non-countable organisms did not differ significantly between different root zones. Variation of the abundance and diversity of countable and non-countable fouling organisms in the Rekawa lagoon could be attributed to the prevailing environmental conditions.

Keywords: fouling organisms, prop roots, Rekawa Lagoon, *Rhizophora mucronata*

Corresponding author: W.M.A.P. Wanasuriya, e-mail: *athma93wanasuriya@gmail.com*

Introduction

Mangroves are well adapted plant communities that grow in inter tidal zone of estuaries and lagoons in tropical in the subtropical areas. They are exposed to hard environmental conditions such as high salinity, low oxygen, strong winds and high sunlight. Buttress roots, flying buttresses, surface roots, prop roots, stilt root, spreading roots, knee roots are the major types of roots presence in mangroves. *Rhizopora muconata* is one of the mangrove species which is consisting prop roots (Srikanth *et al*., 2016). Prop roots from the main stems and the branches grow down into the water below low water level (Alonzo *et al*., 2015). Various aquatic organisms colonize and grow on the surface of those underwater prop roots as fouling communities (Ellison and Farnsworth, 1990). Thus, the root fouling communities indicates the ecological role of mangroves and those communities are important as food for mangrove fishes. Studies on such root fouling communities have been conducted by researches such as Belizean mangrove – root communities (Ellison and Farnsworth, 1990) highlighting the importance of the root fouling communities. However, such studies have not been carried out in Sri Lanka. Specially, being a micro-tidal country, the root fouling community may show differences from the macro-tidal countries, however, new researches need to be undertaken on root fouling communities of Sri Lankan mangroves to discuss this suggestion. All the true mangroves in Rekawa lagoon, in southern Sri Lanka, were selected for this study as it is located nearby and having highest species diversity of true mangroves in the southern Sri Lanka. Therefore, the main objective of the current study was to study the root-fouling communities of *R. mucronanta* growing in a selected Sri Lankan lagoon for filling the above study gap.

Materials and Methods

Rekawa Lagoon (05° 58' N and 80° 50 E) was selected for the current study. During January 2017, twenty *R. muconata* trees were randomly selected from the Rekawa Lagoon and one random root (freely hanging in to water bottom) from each tree was cut and removed. The root length that had been submerged in water was selected as the "study length" for studying the root fouling communities. The study length of the root was divided to equal 4 zones and the diameter in each zone was measured.

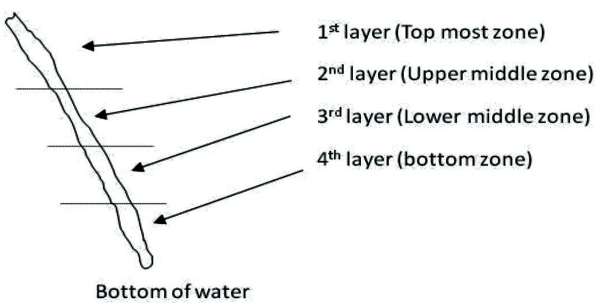

Figure 1: Different zones of the root

Next, all the fouling organisms on each zone were carefully scarped in to separated vials using a sharp knife and they were brought to the laboratory. Using a light microscope, the fouling organisms were identified to the lowest possible taxonomic level. For the countable organisms (who live solitary: for example, isopods, plankton, bivalves, some algae), the abundances of organisms per unit surface area (m^{-2}) of the root were calculated for each root zone. The diversity of roof-fouling organisms for each zone also was calculated using Shannon–Wiener index. The non-countable fouling organisms (who forms colonies: For example, some filamentous Algae, Sponge colonies, Acidian colonies and *Hydra* colonies) were assessed using a simple method adopted from the points (volumetric) method (Hynes, 1950) used in fish gut content analysis. Under this method, at each root zone, each non-countable fouling organism type from that layer were placed on a petri dish as separate lots. Volume of all the lots (Total volume) were visually assigned to 100 points. Next, for each non-countable fouling organism type, its volume was visually compared with the total volume and the volume of the organism type was expressed as a % value out of the total value. Those % volume values were named as "% volume" for each organism types and were compared between the root zones using Kruskal wallis tests.

Data Analysis

Data were summarized in Microsoft Excel and were analyzed using Minitab 16 statistical software. Then they were tested for normality. The data were non-normal even after log and ln transformations. Therefore, the abundance and diversity of the root fouling organisms between the different root zones were compared using separate Kruskal-Wallis tests.

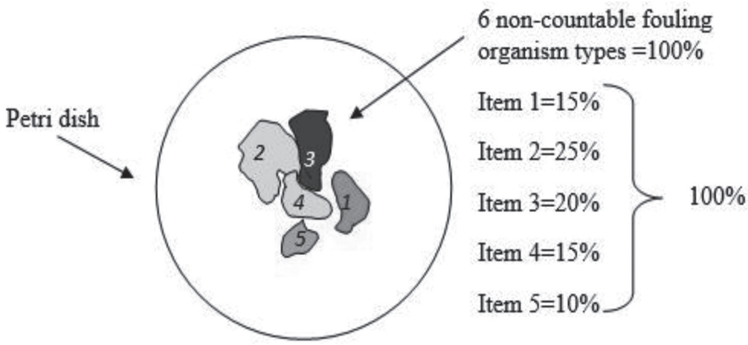

Figure 2: Illustration of the volumetric method used for assessing the non-countable fouling organism types

Results and Discussions

Twenty-seven fouling organism types were identified from all the studied (20) mangrove roots. The identified 16 countable organisms (solitary living animals) are listed in Table 1. Thus it is clear that, the mangrove underwater root surfaces of the Rekawa Lagoon has provided habitats for various fauna types who live solitary. The identified non countable

Table 1: Countable organisms identified

No.	Organism
1	*Asellus* sp. (Subphylum-Crustacea, Order-Isopods)
2	Family – Janiridae (Subphylum-Crustacea, Order-Isopods)
3	Family – Corophiidae (Subphylum-Crustacea, order-Amphipods)
4	Two copepod species (Subphylum-Crustacea, subclass Copepoda)
5	One polychaete species (Phylum-annelida, Class Polychaeta)
6	Young stage of one bivalve species (Class-Bivalvia, Family-Mitilidae)
7	One protists species (Phylum - Sarcodina, Order-Heliozoa)
8	*Melosira* sp. (Bacillariophyta diatom)
9	*Lithodesmium* sp. (Bacillariophyta diatom)
10	*Oscillatoria* sp. (Cyanobacteria)
11	One nematode species
12	Cryptomonas (Phylum - Cryptophyta)
13	*Coscinodiscus radiate* and *Coscinodiscus* sp. (Phylum - Bacillariophyta)
14	Two unidentified phytoplankton species
15	*Discorbis* sp. (Class - Foraminfera)
16	*Chlorella* sp. and *Stigeoclonium* sp. (Family-Chlorellacea)

Table 2: Non-countable organisms identified

No.	Organism
1	*Bostrychia* sp. (Phylum- Rhodophyta)
2	Unidentified sponge (Phylum- porifera)
3	*Hydra* sp. (Phylum-Cnidaria)
4	One species of Calss ascidiacea (Phylum- Chordata)
5	*Ulothrix* sp. (Ulvophyceae)
6	*Wrangelia* sp. (Phylum- Rhodophyta)
7	Ciliate species (Phylum- Ciliophora)
8	Stigeoclonium sp. (Phylum-Chlorophyta)
9	*Cladophora crispata* (Phylum- Clorophyta)

fouling organisms (who form colonies) are listed in Table 2. This indicates that the mangrove underwater root surfaces of the Rekawa Lagoon has provided habitats for both colony-forming and solitary fauna types.

Abundance of countable organisms

As shown in the Figure 3, median abundance of countable organisms (number per m-2 of the root zone) was highest (2461 m^{-2}) in the upper middle zone while the bottom zone (1057 m^{-2}) showed the minimum.

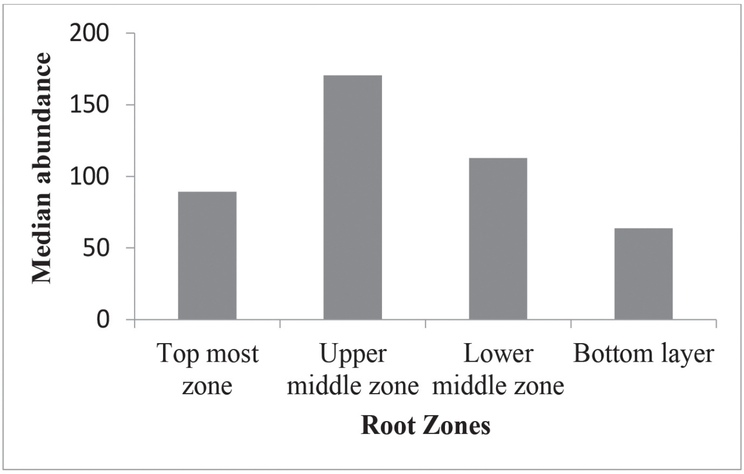

Figure 3: Median abundance of countable Organisms

Diversity of countable organisms (Shannon–Wiener index m^{-2} of the root)

According to Figure 4, upper middle zone showed the highest median diversity (196 m^{-2}) while the bottom layer showed the minimum (70.83 m^{-2}) diversity.

The highest abundance and the highest diversity of organisms in the upper middle zone may have been assisted by relatively calm and clear water prevailing in this middle zone. The lowest abundance and the lowest diversity in the bottom zone could be due to suspending bottom sediments. The low abundances and diversities in the uppermost zone could be due to the reason that the upper most layer is frequently disturbed by surface waves.

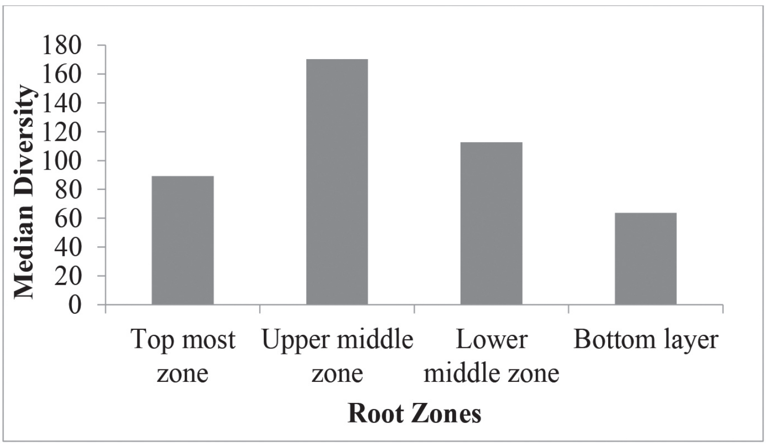

Figure 4: Median diversity of countable Organisms

Table 3: The mean Percent volume of non-countable organisms between the different root

	Bostrychia sp. (Rhodophyta)	Sponge sp. (Porifera)	*Hydra* sp. (Cnidaria)	Calss Ascidiacea (Chordata)	*Wrangelia* sp. (Rhodophyta)	*Ulothrix* sp. (Ulvophyceae)	*Cladophora* sp. (Clorophyta)	Ciliate species sp. (Ciliophora)	*Stigeoclonium* sp. (Chlorophyta)
Top most zone	18	27	3	2	3.25	17.5	11	12.75	5.75
Upper middle zone	18	20.4	0.75	1.1	1.85	30.75	8.25	11.75	6.25
Lower middle zone	32	16.9	1.2	3	2.6	18.7	13.2	9.15	3.1
Bottom zone	34	21.5	0.5	12.5	5.5	19.75	0.75	5.5	0

Percent volume of non-countable organisms (%volume m^{-2} of the root)

Due to unknown reason, the median %volume of non-countable organisms did not differ between the different root zones (Table 3).

Conclusions

The solitary living fouling organisms showed vertical zonation possibly due to physical disturbances such as water turbulence and suspending sediments. However, the colony-forming fouling organisms did not show such vertical patterns. The current research involved limited number of samples due to time limitations and this research should be extended with more replicates for better conclusions.

References

Ellison AM, Farnsworth EJ. 1990. The ecology of Belizean mangrove-root fouling communities. I. Epibenthic fauna are barriers to isopod attack of red-mangroves. Journal of Experimental Marine Biology and Ecology 142:91-104.

Hynes, H.B. N. 1950. The food of the freshwater sticklebacks (*Gastrosteus aculeatus* and *Pygosteus pungitius*) with a review of methods used in studies of the food of fishes. Journal of Animal Ecology, 19:36-58.

Méndez-Alonzo, R., Moctezuma, C., Ordoñez, V.R., Angeles, G., Martínez, A.J., López-Portillo, J., 2015. Root biomechanics in *Rhizophora mangle*: Anatomy, morphology and ecology of mangrove's flying buttresses. Annals of Botany, 115, 833–840.

Srikanth, S., Lum, S.K.Y., Chen, Z., 2016. Mangrove root: Adaptations and ecological importance. Trees - Structure and Function. doi:10.1007/s00468-015-1233-0.

Dr. W.C.P. Egodawatte, Department of Plant Sciences, Faculty of Agriculture, Rajarata University of Sri Lanka, Sri Lanka

Dr. (Ms.) L. Pradheepan, Department of Agronomy, Faculty of Agriculture, University of Jaffna, Sri Lanka

Dr. (Ms.) D.A.U.D. Devasinghe, Department of Plant Sciences, Faculty of Agriculture, Rajarata University of Sri Lanka, Sri Lanka

Author Instructions

Script

The script should be free of errors and typewritten using double spacing throughout on one side A4 size white bond paper, leaving at least 3 cm margins on either side or liberal spacing at the top and bottom of each page. Sheets should be numbered consecutively.

Length and Style

The length of the paper should not exceed 15 A4 pages. Minimum number of pages should be 6 A4 pages. The style of writing should conform to acceptable English usage. Slang, jargon, unauthorized abbreviations, abbreviated phrasings and the like, should be avoided.

Manuscript Layout

Manuscript for article should be organized as follows: Title, Abstract, Keywords, Introduction, Materials and Methods, Results and Discussion, Conclusion, Acknowledgement and References. Pages should be numbered consecutively and arranged in the following order.

Page 1

Title Page

Include the title of paper, names and affiliations of all authors including e-mail address, telephone and fax number of corresponding author. Submitted manuscripts must list full names for all authors; that is, full first/given name(s), middle initial(s), and last/surname(s). Title should be concise, informative and typed in 'Sentence case' bold letters.

Page 2

Abstract:

No more than 250 words for full length articles. The abstract should not contain any references and should be able to stand on its use without modification in abstracting journals. It should outline objectives and methodology together with important results and conclusions.

Keywords

A maximum of six keywords may include the name of an organism (common and scientific), method or other words or phrases that represent the subject of the study.

Page 3 onwards

Main Body

Introduction

It should be concise and well-focused to the research work done.

Materials and Methods

New methods may be described in detail with an indication of their limitations. Established methods can be mentioned with appropriate references. Sufficient detail should be included to allow direct repetition of the work by others. A paper reporting the results of the experimental investigations on human subjects or on animal must include a statement, under methods and materials, to the effect that the relevant national or other ethical guidelines have been adhered to. Statistical analyses done should be mentioned where applicable.

Results and Discussion

The results should be concisely and logically presented. Only data essential for the main conclusions emerging from the study should be included. Repetition of the same results in figures, tables or text should be avoided. Long discussions should be avoided. The discussion should deal with the interpretation of results. It should logically relate new findings of earlier ones.

Conclusion

Unqualified statements and conclusions not completely supported by data should be avoided. All hypotheses should be clearly identified as such.

Acknowledgements

Acknowledgements should be brief and made for funding sources, scientific and technical assistance and not for routine help in preparing manuscripts. If a significant part of the research was performed in an institution other than in those indicated by the authors' affiliations given in the title page, this fact should be acknowledged.

References

References to the literature must be indicated in the text and tables as following the general procedure. The reference should be in alphabetical order at the end of the manuscripts under the same caption. Unpublished data and personal communications should not be listed under reference but may be mentioned in the text. Reference to work 'in press' implies its acceptance for publication and may be listed under references. In each reference, all the initials of the author must be given after the surname. The year of publication should follow the author name. This should be followed by the full title of the referred publication.

When journal articles are listed, the journal names should be given in full and followed by the volume number, the issue number in parentheses and then the inclusive pages. When books are listed, the order should be: author(s), year, book title, volume number, edition, pagination/inclusive pages, publisher and place of publication. The book title should be indicated in italics. When sections of a book are listed, the order should be: authors of section, year, title of the section, title of the book, edition, inclusive pages, publisher and place of publication.

Citation in the text

Cite references in the text by name and year in parentheses. Some examples:

…fully hydrogenated fats are blended with liquid oils as the feed stocks of interesterification (Zhang *et al*., 2000).

…. with low or zero trans fatty acids and the results were promising (Zhang *et al*., 2001; Zhang *et al*., 2006; Goli *et al.*, 2008).

……trans-free margarine formulations and most widely used enzyme for the interesterification is Lipozyme TL IM (Ferreira-Dias, 2013).

…..fatty acids can be obtained by enzymatic interesterification (Huang and Akoh, 1994). This result was later contradicted by Becker and Seligman (1996).

Reference list

Journals articles

1. Single author
   Gil, A. 2002. Polyunsaturated fatty acids and inflammatory diseases. Biomedicine and Pharmacotherepy, 56:388–396.
2. Two authors
   Huang, K.H. and Akoh, C.C. 1994. Lipase-catalyzed incorporation of n-3 polyunsaturated fatty acids into vegetable oils. Journal of the American Oil Chemists' Society, 71:1277–1280.
3. More than two authors
   Zhang, H., Xu, X., Mu, H., Nilsson, J., Adler-Nissen, J. and Høy, C.E. 2000. Lipozyme IM-catalyzed interesterification for the production of margarine fats in a 1 kg scale stirred tank reactor. European Journal of Lipid Science and Technology, 102:411–418.

Books and other monographs

4. Chapter in book

Gordon, M.H. 2001. The development of oxidative rancidity. In: Pokorny, J., Yanishlieva, N. and Gordon, M. (eds) Antioxidants in Food – Practical Applications. CRC Press, Washington, pp 7-225.

Web references

The full URL should be given with the date when the reference was last accessed. Any further information, if known (DOI, author names, dates, reference to a source publication, etc.), should also be given.

Abbreviations and Symbols

Unless common, these should be defined when first used, and not included in the abstract. The SI system of units should be used wherever possible. If measurements were made in units other than SI, the data should be reported in the same units followed by SI units in brackets. E.g. 5290 ft (1610m)

Formula and Equations

Equations should be typewritten and quadruple spaced. They should be started on the left margin on the number placed in parentheses to the right of the equation.

Nomenclature

Scientific names of plants and animals will be printed in italics, and should be either underlined or typed in italics in the manuscript. In the first citation, genus species and authority must be given. E.g. *Scirtothrips dorsalis* L. In later citation, the generic name may be abbreviated. E.g. *S. dorsalis.*

Tables

Table should be clear and intelligible without references to the text, and should not repeat data available elsewhere in the paper. They should be typed on A4 size paper and numbered consecutively with Arabic numerals. If a table must be continued, a second sheet should be used and all the headings repeated. Tables should always be cited in text in consecutive numerical order.

The number of columns or rows in each table should have a title which makes its general meaning clear without reference to the text. All tables column should have explanatory headings. Units of measurements, if any, should be indicated in parentheses in the headings of each column. Vertical lines should not be used and horizontal lines should be used only in the heading at the bottom of the table. Footnotes to table should be placed directly below the table and should be indicated by subscript lower case italic letters (a, b, c, etc.). The preferred position of tables should be indicated in pencil in the manuscript.

Figures (Illustrations)

Should be kept to a minimum and their total should not exceed ten. If previously published illustrations are essential, the copyright holder's written permission should be obtained. All illustrations are considered as figures, and each graph, drawing or photograph should be numbered in sequence with Arabic numerals. The required lettering should be indicated on a photocopy of the illustration. Scanned figures should be of high quality, to fit the proportions of the printed page (12 x 17 cm), not larger than 20 x 30 cm.

Each figure should carry a legend so written that the general meaning of the figure can be understood without reference to the text. Figure legends should be typed with double-spacing on a separate sheet and placed at the end of the paper. The maximum number of words per legend should be 40. Where magnifications are used, they should be stated. The approximate position for each figure should be indicated in the margin of the text.

Color illustrations are not considered for publication. Illustrations in black and white with non-mounted high quality photographs are acceptable. Magnification should be indicated with the scale line on the photograph. The author's name and figure number should be given on the back of each photograph. If you include figures that have already been published elsewhere, you must obtain permission from the copyright owner(s) for both the print and online format.

Changes in Authorship

Authors are expected to consider carefully the list and order of authors before submitting their manuscript and provide the definitive list of authors at the time of the original submission. Any addition, deletion or rearrangement of author names in the authorship list should be made only before the manuscript has been accepted and only if approved by the journal Editor. Only in exceptional circumstances will the Editor consider the addition, deletion or rearrangement of authors after the manuscript has been accepted.

Copyright

Subscribers may reproduce tables of contents or prepare lists of articles including abstracts for internal circulation within their institutions. Permission of the Publisher is required for resale or distribution outside the institution and for all other derivative works, including compilations and translations. If excerpts from other copyrighted works are included, the author(s) must obtain written permission from the copyright owners and credit the source(s) in the article.

Manuscript Submission

Manuscript prepared in MS word as .docx format (Word 2007 or higher) according to the guidelines should be submitted electronically to the email: jdzajournal@gmail.com

Contact us:

The Chief Editor,
Journal of Dry Zone Agriculture, Faculty of Agriculture,
University of Jaffna, Ariviyal Nagar, Kilinochchi, Sri Lanka
Tel: (+94) 212060175
e-mail: jdzajournal@gmail.com
URL: www.jdza.jfn.ac.lk